



**US Army Corps
of Engineers®**

Sacramento District

Engineering Division

Sutter Basin Pilot Feasibility Report - Environmental Impact Report / Supplemental Environmental Impacts Statement

Butte and Sutter Counties, California

Civil Design Appendix

October 2013

CONTENTS

CONTENTS

CHAPTER 1 – INTRODUCTION

- 1.1 Project Description
- 1.2 Purpose and Scope
- 1.3 Coordination

CHAPTER 2 – DESIGN CONSIDERATIONS

- 2.1 General
- 2.2 Alignment and Stationing
- 2.3 Reaches and Alternatives
- 2.4 Existing Conditions and Remediation Measures
- 2.5 Encroachments
- 2.6 Real Estate Requirements
- 2.7 Quantity Development

CHAPTER 3 – ALTERNATIVE DESCRIPTIONS

- 3.1 General
- 3.2 Alternative Descriptions

LIST OF FIGURES

- Plate 1-1 Project Area (Alternative SB1 - No Action)
- Plate 1-2 Alternative SB2
- Plate 1-3 Alternative SB3
- Plate 1-4 Alternative SB4
- Plate 1-5 Alternative SB5
- Plate 1-6 Alternative SB6
- Plate 1-7 Alternative SB7
- Plate 1-8 Alternative SB8
- Figure 1-1 – Map of Reaches
- Figure 2-1 – Levee Improvement Type 1
- Figure 2-2 – Levee Improvement Type 2
- Figure 2-3 – Levee Improvement Type 3
- Figure 2-4 – Levee Improvement Type 4
- Figure 2-5 – Levee Improvement Type 5
- Figure 2-6 – Levee Improvement Type 6
- Figure 2-7 – Levee Improvement Type 7
- Figure 2-8 – Levee Improvement Type 8
- Figure 2-9 – Levee Improvement Type 9
- Figure 2-10A – Reach S5-A (Improvement Type 4 for 25% of Reach Length)

- Figure 2-10B – Reach S5-A (Improvement Type 6 for 100% of Reach Length)
- Figure 2-11A – Reach S5-B (Improvement Type 4 for 75% of Reach Length)
- Figure 2-11B – Reach S5-B (Improvement Type 6 for 75% of Reach Length)
- Figure 2-12A – Reach S5-C (Improvement Type 4 for 25% of Reach Length)
- Figure 2-12B – Reach S5-C (Improvement Type 6 for 75% of Reach Length)
- Figure 2-12C – Reach S5-C (Improvement Type 9 for 100% of Reach Length)
- Figure 2-13A – Reach S5-D (Improvement Type 4 for 10% of Reach Length)
- Figure 2-13B – Reach S5-D (Improvement Type 6 for 50% of Reach Length)
- Figure 2-13C – Reach S5-D (Improvement Type 9 for 100% of Reach Length)
- Figure 2-14A – Reach S7-D (Improvement Type 4 for 10% of Reach Length)
- Figure 2-14B – Reach S7-D (Improvement Type 6 for 50% of Reach Length)
- Figure 2-14C – Reach S7-D (Improvement Type 9 for 100% of Reach Length)
- Figure 2-15A – Reach S7-E (Improvement Type 4 for 10% of Reach Length)
- Figure 2-15B – Reach S7-E (Improvement Type 6 for 75% of Reach Length)
- Figure 2-15C – Reach S7-E (Improvement Type 9 for 100% of Reach Length)
- Figure 2-16A – Reach S7-F (Improvement Type 4 for 10% of Reach Length)
- Figure 2-16B – Reach S7-F (Improvement Type 6 for 75% of Reach Length)
- Figure 2-16C – Reach S7-F (Improvement Type 9 for 100% of Reach Length)
- Figure 2-17A – Reach S7-G (Improvement Type 4 for 10% of Reach Length)
- Figure 2-17B – Reach S7-G (Improvement Type 6 for 100% of Reach Length)
- Figure 2-18A – Reach S7-H (Improvement Type 4 for 10% of Reach Length)
- Figure 2-18B – Reach S7-H (Improvement Type 6 for 100% of Reach Length)
- Figure 2-19A – Reach S7-I (Improvement Type 4 for 10% of Reach Length)
- Figure 2-19B – Reach S7-I (Improvement Type 6 for 100% of Reach Length)
- Figure 2-20A – Reach S7-J (Improvement Type 4 for 10% of Reach Length)
- Figure 2-20B – Reach S7-J (Improvement Type 6 for 50% of Reach Length)
- Figure 2-21A – Reach S4-South/S6-South (Improvement Type 7 for 50% of Reach Length)
- Figure 2-21B – Reach S4-South/S6-South (Improvement Type 8 for 50% of Reach Length)
- Figure 2-22A – Reach S4-West/S6-West (Improvement Type 7 for 75% of Reach Length)
- Figure 2-22B – Reach S4-West/S6-West (Improvement Type 8 for 25% of Reach Length)
- Figure 2-23A – Reach S4-North (Improvement Type 7 for 50% of Reach Length)
- Figure 2-23B – Reach S4-North (Improvement Type 8 for 50% of Reach Length)
- Figure 2-24 – Reach S9-G (Improvement Type 8 for 100% of Reach Length)
- Figure 2-25 – Reach S9-H (Improvement Type 8 for 100% of Reach Length)
- Figure 2-26 – Reach S9-I (Improvement Type 8 for 100% of Reach Length)
- Figure 2-27 – Reach S10 (Improvement Type 8 for 100% of Reach Length)
- Figure 2-28A – Reach S11 (Improvement Type 7 for 50% of Reach Length)
- Figure 2-28B – Reach S11 (Improvement Type 8 for 50% of Reach Length)
- Figure 2-29A – Reach S12 (Improvement Type 6 for 25% of Reach Length)
- Figure 2-29B – Reach S12 (Improvement Type 8 for 75% of Reach Length)

LIST OF TABLE

- Table 2-1 – Existing Levee Segments
- Table 2-2 – New Levee Segments
- Table 2-3 – Draft Array of Potential Alternatives
- Table 2-4 – Average Geometry of Existing Levee Segments
- Table 2-5A – Levee Remediation Measures (by Percentage of Reach Length)
- Table 2-5B – Levee Remediation Measures (by Length in Linear Feet)
- Table 3-1 – Draft Array of Potential Alternatives

ENCLOSURES

- Enclosure 1, Evaluation of Preliminary Array of Conceptual Alternatives
- Enclosure 2, Review & Incorporation of the Data from the EIP
- Enclosure 3, Design of New Levee Segments
- Enclosure 4, Encroachment Improvements & Estimates

REFERENCES

- USACE EM 1110-2-1913, “Design and Construction of Levees”, 30 April 2000
- CESP-K-ED-G, SOP-EDG-03 “Geotechnical Levee Practice”, 11 April 2008

ACRONYMS

CCEL Cherokee Canal East Levee (Left Levee)
EIP Early Implementation Project (local sponsor’s Plan)
FRWL Feather River West Levee (Right Levee)
MEIP Modified EIP (COE’s modifications to the EIP)
O&M Operation and Maintenance
ROW Right of Way
SBEL Sutter Bypass East Levee (Left Levee)
SBL Sutter Basin Levee System
WCEL Wadsworth Canal East Levee (Left Levee)
WCWL Wadsworth Canal West Levee (Right Levee)

CHAPTER 1 – INTRODUCTION

1.1 Project Description

The existing Sutter Basin Levee System (SBLS) consists of four mainline levees which are Feather River West Levee (FRWL or right levee), Sutter Bypass East Levee (SBEL or left levee), Wadsworth Canal East Levee (WCEL or left levee) and Wadsworth Canal West Levee (WCWL or right levee), and Cherokee Canal East Levee (CCEL or left levee) surrounding the communities of Yuba City, Live Oak, Gridley, Biggs and other smaller towns in Sutter and Butte Counties, California.

During the preliminary phase of this Feasibility Study, many potential remediation measures were considered and combined to form a preliminary array of conceptual alternatives. Through plan formulation process, the preliminary array was refined to a draft array that includes 8 potential alternatives:

- SB-1: No Action.
- SB-2: Minimal Fix-in-place the FRWL from Star Bend to Sunset Weir
- SB-3: Yuba City Ring Levee
- SB-4: Little “J” Levee
- SB-5: Fix-in-place the FRWL from Star Bend to Thermalito Afterbay
- SB-6: Fix-in-Place the FRWL, SBEL and WCEL
- SB-7: Fix-in-Place the FRWL from Laurel Avenue to Sunset Weir
- SB-8: Fix-in-Place the FRWL from Laurel Avenue to Thermalito Afterbay.

The draft array was analyzed and refined to a final array that includes 3 alternatives, SB-1, SB-7 and SB-8. During the final phase of this Feasibility Study, alternatives SB-7 and SB-8 were further evaluated to determine the Recommended Plan for final recommendation. (Plates 1-1 to 1-8 depict the extent of the potential alternatives included in the draft array).

1.2 Purpose and Scope

The purpose of this report is to provide a summary of the civil design evaluation of and consideration for the draft array. The evaluation is a refinement of the preliminary analysis completed for the conceptual alternatives and conforms to the minimum requirements for the development of Class 4 estimate for reconnaissance level analysis. (The preliminary analysis of the conceptual alternatives is documented in enclosure 1, Evaluation of Preliminary Array of Conceptual Alternatives. Classification of the estimate was in accordance with EM 1110-2-1302, Civil Works Cost Engineering, which was based on ASTM E 2516-06, Standard Classification for Cost Estimate Classification System.)

The civil design evaluation of and consideration for alternatives SB-7 and SB-8 of the final array are discussed in paragraph 2.9 of the Engineering Appendix and conform to the minimum requirements for the development of Class 3 estimate for feasibility level analysis. (Enclosure 2, Review & Incorporation of the EIP, of this report is an extension of paragraph 2.9 of the Engineering Appendix.)

(Enclosure 2, Review & Incorporation of the EIP, of this report is an extension of paragraph 2.9 of the Engineering Appendix.)

1.3 Coordination

Existing information and information from the local sponsor's Early Implementation Plan (EIP) were utilized for civil design considerations and evaluations. Close coordination with the local sponsor's design teams took place throughout the study.

CHAPTER 2 – DESIGN CONSIDERATIONS

2.1 General

This chapter provides a summary of the civil design evaluation of and consideration for the draft array of 8 potential alternatives, SB1 to SB8. Design considerations include engineering guidance or methodology used and assumptions.

2.2 Alignment and Stationing

Three levees considered were the FRWL (right levee), SBEL (left levee) and WCEL (left levee).

The project levee alignments and stationing for the SBEL and the WCEL were developed based on the surveyed data from the National Levee Data Base. The stationing for the SBEL begins with station 0+00 at the confluence of the SBEL at the FRWL and increases in an upstream (North) direction. The stationing for the WCEL begins with station 0+00 at the confluence of the WCEL at the SBEL and increases in an upstream (North) direction.

The project levee alignment and stationing for the FRWL, adopted from the 65% EIP, follows the existing levee centerline of the FRWL except at Star Bend where the levee alignment follows the centerline of the setback levee. The stationing begins with station 10+00 at the confluence of the FRWL at the SBEL and increases in an upstream (North) direction. This levee stationing conforms to the existing levee centerline and accounts for recent changes in the alignment, such as the Star Bend Setback Levee (between station 478+68 and station 512+00). At locations where levee relocations (e.g. roughly between station 1432+70 and station 1754+30 etc.) are proposed, supplementary levee alignments stationing necessary for designs and analyses were established.

2.3 Reaches and Alternatives

2.3.1 Reaches

A total of 28 reaches were considered. 16 of these reaches are the existing levee segments (see table 2-1). The other 12 reaches are either proposed setback or new levee segments (see table 2-2). The reaches are shown in figure 1-1.

Table 2-1 – Existing Levee Segments

Reach	Alignment	Type	STA. (Beg.)	STA. (End.)
S5-A-Upper	FRWL	Existing Levee	1958+00	2372+17
S5-A-Lower	FRWL	Existing Levee	1825+00	1958+00
S5-B	FRWL	Existing Levee	1432+00	1825+00
S5-C	FRWL	Existing Levee	1129+00	1432+00
S5-D	FRWL	Existing Levee	816+00	1129+00
S7-D	FRWL	Existing Levee	603+00	816+00
S7-E-Upper	FRWL	Existing Levee	512+00	603+00
S7-E-Middle	FRWL	Existing Levee	479+00	512+00
S7-E-Lower	FRWL	Existing Levee	420+00	479+00
S7-F-Upper	FRWL	Existing Levee	200+00	420+00
S7-F-Middle	FRWL	Existing Levee	47+00	200+00
S7-F-Lower	FRWL	Existing Levee	10+00	47+00
S7-G	SBEL	Existing Levee	0+00	400+00
S7-H	SBEL	Existing Levee	400+00	493+00
S7-I	SBEL	Existing Levee	493+00	922+16
S7-J	WCEL	Existing Levee	0+00	244+00

Table 2-2 – New Levee Segments

Reach	Alignment	Type	STA. (Beg.)	STA. (End.)
S4-South	YCRL	New Ring Levee	0+00	280+00
S4-West	YCRL	New Ring Levee	280+00	490+00
S4-North	YCRL	New Ring Levee	490+00	750+00
S6-South	YCJL	New “J” Levee	0+00	280+00
S6-West-lower	YCJL	New “J” Levee	280+00	490+00
S6-West-upper	YCJL	New “J” Levee	490+00	550+00
S9-G	SBEL	Setback Levee	0+00	400+00
S9-H	SBEL	Setback Levee	400+00	493+00
S9-I	SBEL	Setback Levee	493+00	922+16
S10	FRWL	Setback Levee	1958+00	2372+17
S11	FRWL	Setback Levee	47+00	200+00
S12	FRWL	Setback Levee	479+00	512+00

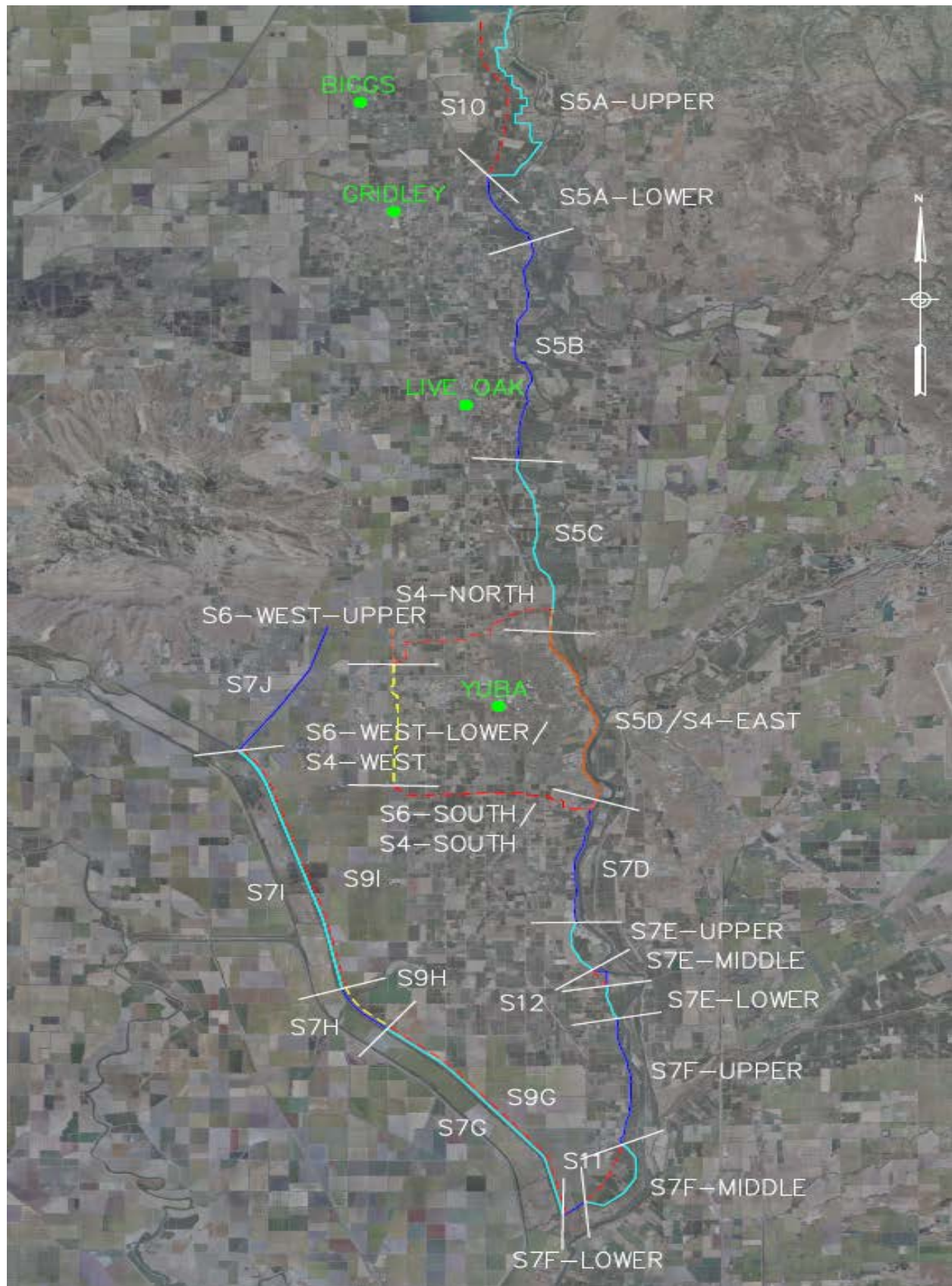


Figure 1-1 – Map of Reaches

2.3.2 Alternatives

Through plan formulation eight potential alternatives were retained from the preliminary array for further evaluation, these include:

- SB-1: No Action.
- SB-2: Minimal Fix-in-place the FRWL from Star Bend to Sunset Weir
- SB-3: Yuba City Ring Levee
- SB-4: Little “J” Levee
- SB-5: Fix-in-place the FRWL from Star Bend to Thermalito Afterbay
- SB-6: Fix-in-Place the FRWL, SBEL and WCEL
- SB-7: Fix-in-Place the FRWL from Laurel Avenue to Sunset Weir
- SB-8: Fix-in-Place the FRWL from Laurel Avenue to Thermalito Afterbay.

Table 2-3 summarizes the reaches included in each of the 8 potential alternatives.

Table 2-3 – Draft Array of Potential Alternatives

Reach	SB-1	SB-2	SB-3	SB-4	SB-5	SB-6	SB-7	SB-8
S5-A-Upper				X	X	X		X
S5-A-Lower				X	X	X		X
S5-B				X	X	X		X
S5-C		X		X	X	X	X	X
S5-D		X	X	X	X	X	X	X
S7-D		X			X	X	X	X
S7-E-Upper		X			X	X	X	X
S7-E-Middle		X			X	X	X	X
S7-E-Lower						X	X	X
S7-F-Upper						X	X	X
S7-F-Middle						X		
S7-F-Lower						X		
S7-G						X		
S7-H						X		
S7-I						X		
S7-J						X		
S4-South			X					
S4-West			X					
S4-North			X					
S6-South				X				
S6-West-lower				X				
S6-West-upper				X				
S9-G								
S9-H								
S9-I								
S10								
S11								
S12								

2.4 Existing Condition and Remediation Measures

2.4.1 Existing Condition

Based on the result of preliminary geotechnical investigations, the average geometry of the existing levees were defined and shown in table 2-4.

Table 2-4 – Average Geometry of Existing Levee Segments

Reach	Length (LF)	Height (LF)	Crest Width (LF)	LS Slope (H:V)	WS Slope (H:V)	Base Width (LF)
S5-A-Upper	41,417	17.5	20	2:1	3:1	107.5
S5-A-Lower	13,300	17.5	20	2:1	3:1	107.5
S5-B	39,300	12.5	20	2:1	3:1	82.5
S5-C	30,300	17.5	16	2:1	3:1	103.5
S5-D	31,300	25	15	2:1	3:1	140
S7-D	21,300	25	15	2:1	3:1	140
S7-E-Upper	9,100	22.5	17	2:1	3:1	127.5
S7-E-Middle	3,300	22.5	17	2:1	3:1	127.5
S7-E-Lower	5,900	22.5	17	2:1	3:1	127.5
S7-F-Upper	22,000	22.5	13	2:1	3:1	125.5
S7-F-Middle	15,300	22.5	13	2:1	3:1	125.5
S7-F-Lower	3,700	22.5	13	2:1	3:1	125.5
S7-G	40,000	22.5	22	2:1	3:1	134.5
S7-H	9,300	20	22	2:1	3:1	122
S7-I	42,916	20	22	2:1	3:1	122
S7-J	24,400	15	24	2:1	3:1	99

2.4.2 Proposed Levee Remediation Measures

Based on preliminary geotechnical design recommendations, 9 conceptual typical levee remediation measures were developed and shown in figure 2-1 through 2-9.

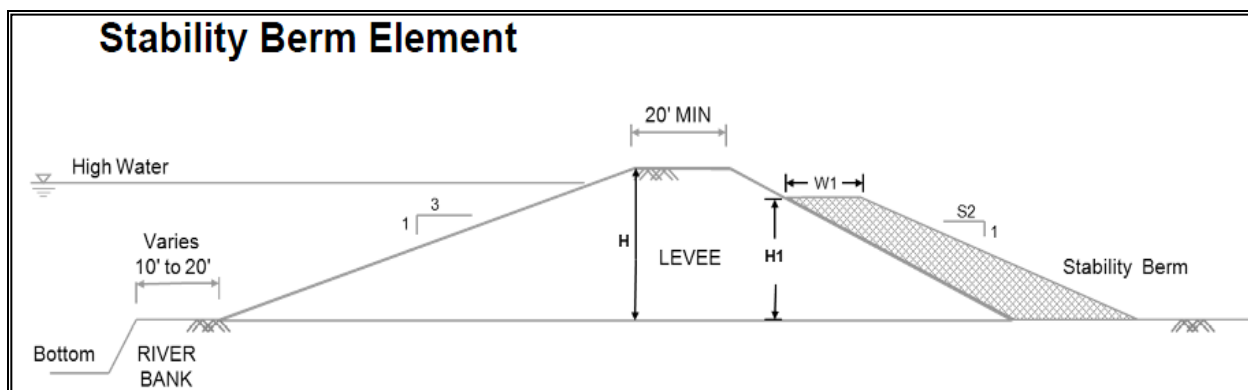


Figure 2-1 – Levee Improvement Type 1

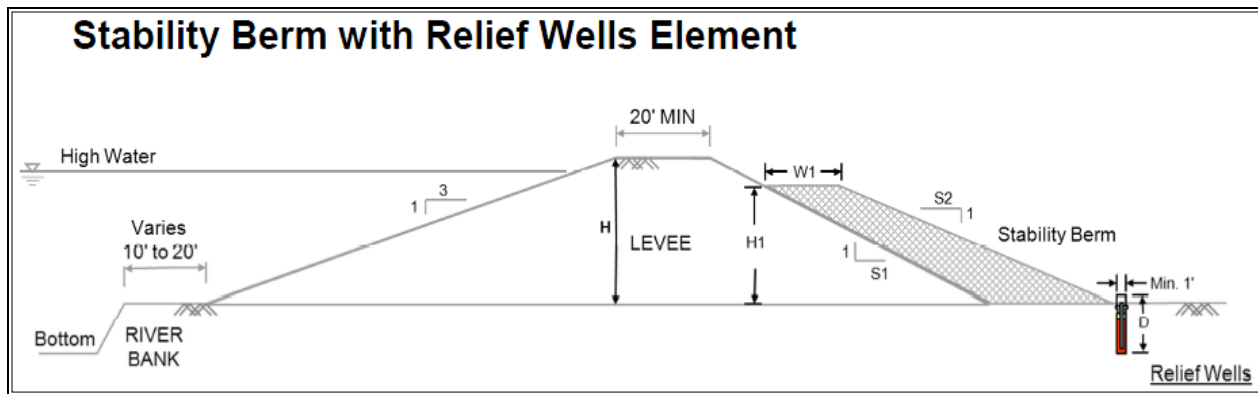


Figure 2-2 – Levee Improvement Type 2

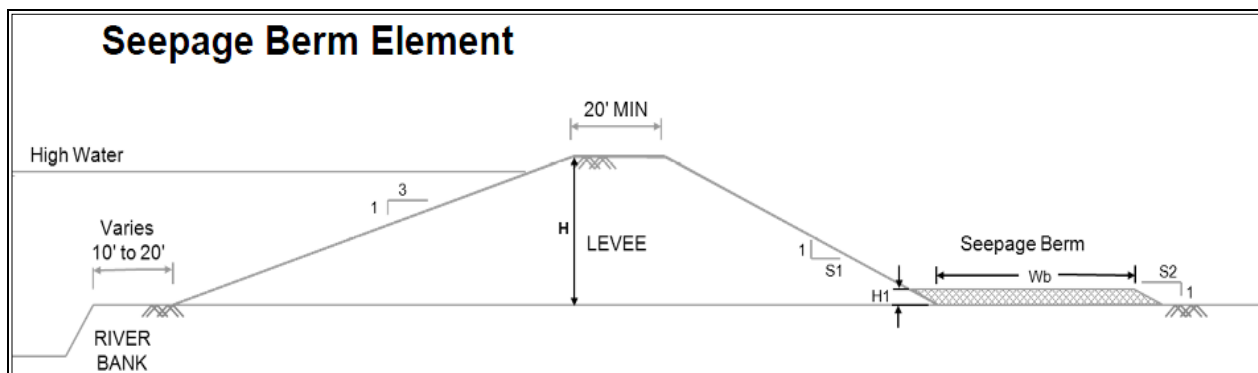


Figure 2-3 – Levee Improvement Type 3

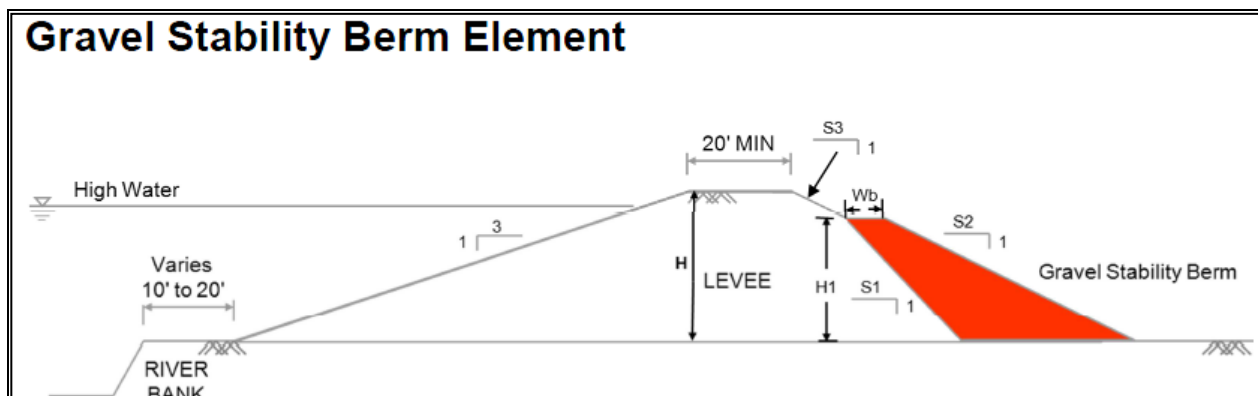


Figure 2-4 – Levee Improvement Type 4

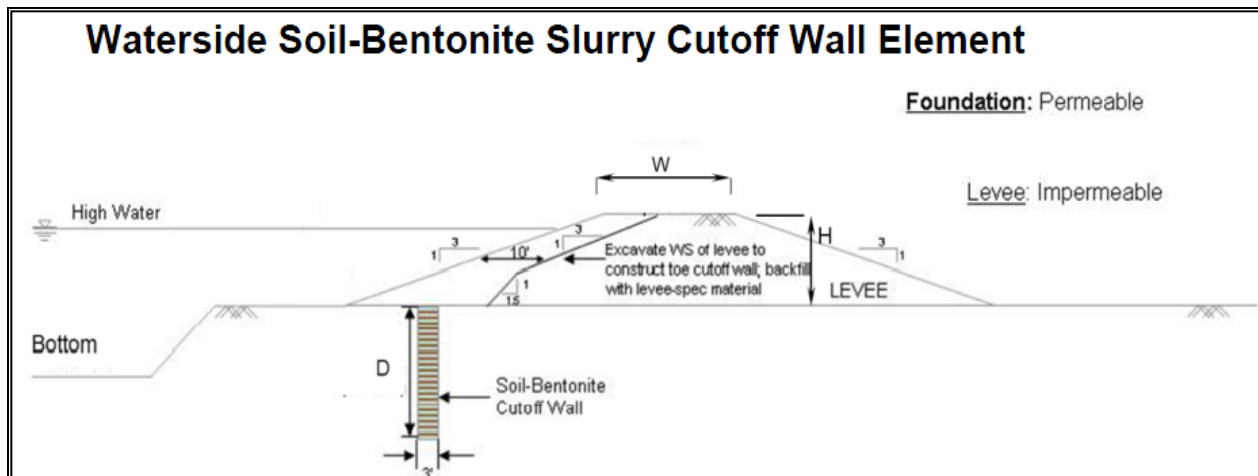


Figure 2-5 – Levee Improvement Type 5

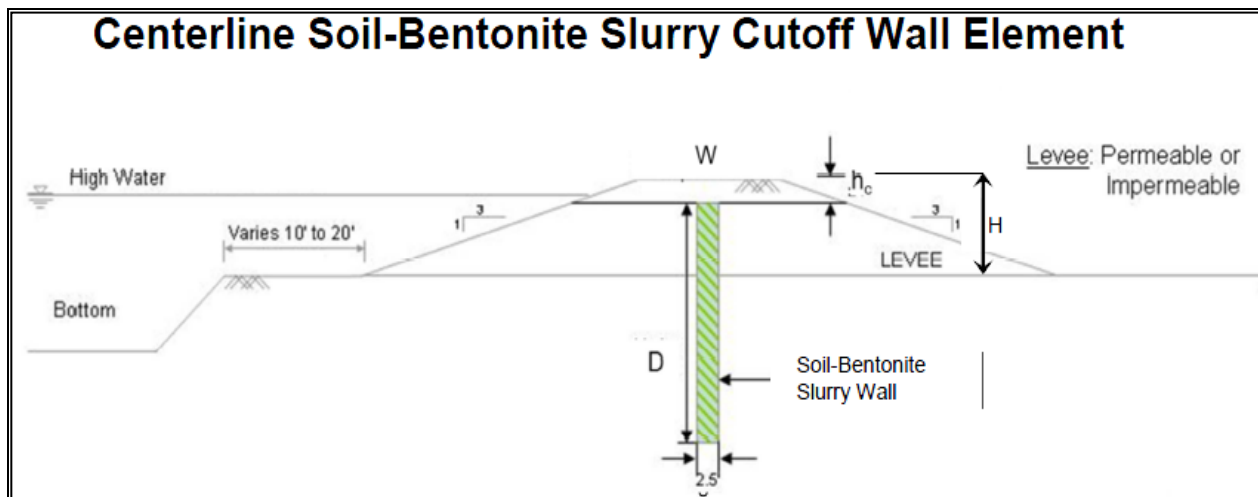


Figure 2-6 – Levee Improvement Type 6

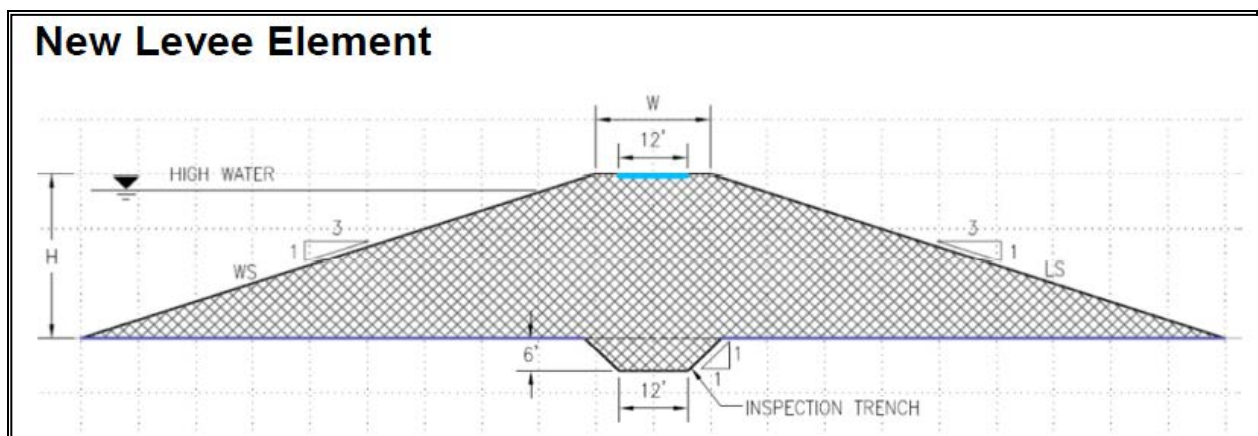


Figure 2-7 – Levee Improvement Type 7

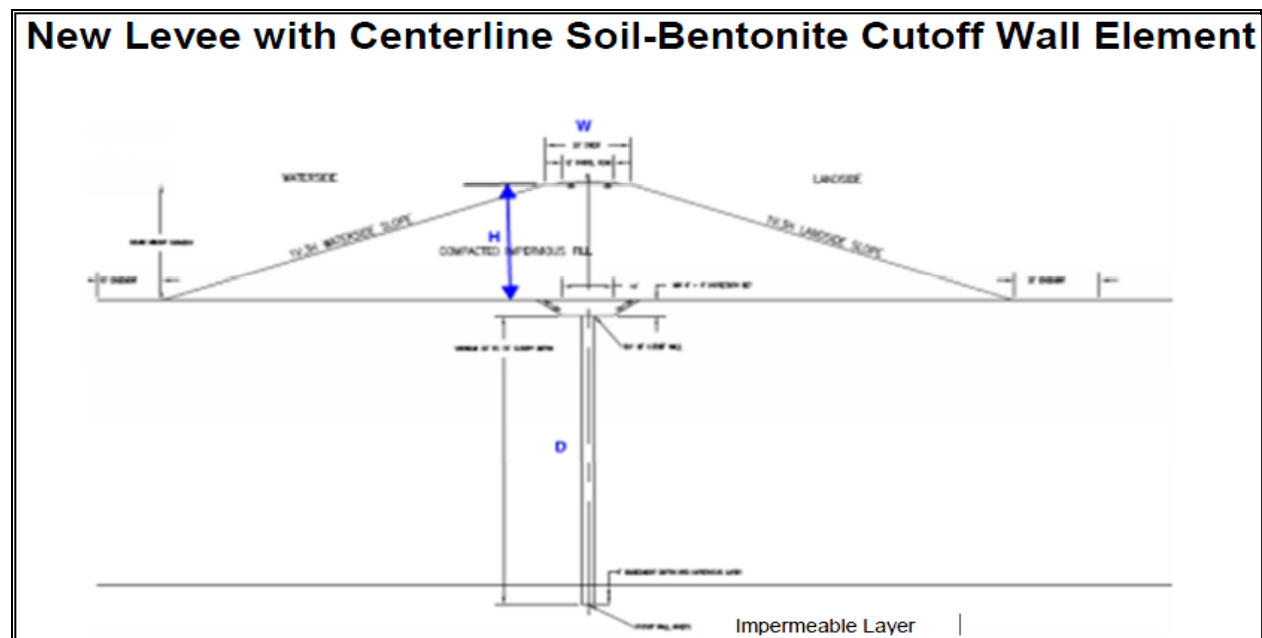


Figure 2-8 – Levee Improvement Type 8

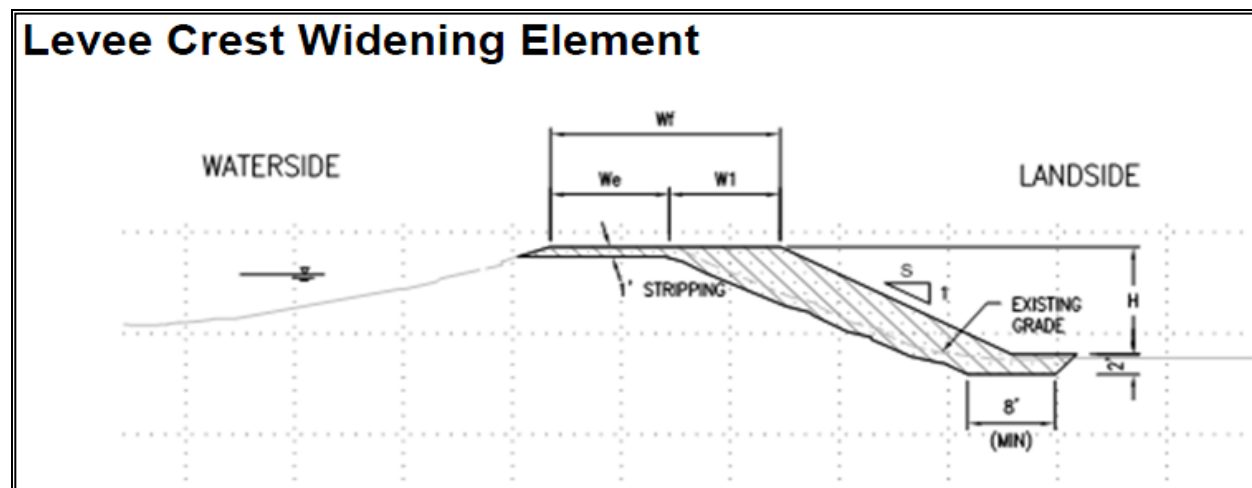


Figure 2-9 – Levee Improvement Type 9

The typical levee remediation measures (shown in figure 2-1 through 2-9) were assigned to each of the 28 reaches as shown in table 2-5A and 2-5B:

Table 2-5A – Levee Remediation Measures (by Percentage of Reach Length)

Reach	Length (LF)	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	Type 8	Type 9
S5-A-Upper	41,417				25%		100%			
S5-A-Lower	13,300				25%		100%			
S5-B	39,300				75%		75%			
S5-C	30,300				25%		75%			100%
S5-D	31,300				10%		50%			100%
S7-D	21,300				10%		50%			100%
S7-E-Upper	9,100				10%		75%			100%

S7-E-Middle	3,300				10%		75%			100%
S7-E-Lower	5,900				10%		75%			100%
S7-F-Upper	22,000				10%		75%			100%
S7-F-Middle	15,300				10%		75%			100%
S7-F-Lower	3,700				10%		75%			100%
S7-G	40,000				10%		100%			
S7-H	9,300				10%		100%			
S7-I	42,916				10%		100%			
S7-J	24,400				10%		50%			
S4-South	28,000							50%	50%	
S4-West	21,000							75%	25%	
S4-North	26,000							50%	50%	
S6-South	28,000							50%	50%	
S6-West-lower	21,000							75%	25%	
S6-West-upper	6,000							75%	25%	
S9-G	40,000								100%	
S9-H	9,300								100%	
S9-I	42,916								100%	
S10	41,417								100%	
S11	15,300							50%	50%	
S12	3,300						25%		75%	

Table 2-5B – Levee Remediation Measures (by Length in Linear Feet)

Reach	Length (LF)	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	Type 8	Type 9
S5-A-Upper	41,417				10,354		41,417			
S5-A-Lower	13,300				3,325		13,300			
S5-B	39,300				29,475		29,475			
S5-C	30,300				7,575		22,725			30,300
S5-D	31,300				3,130		15,650			31,300
S7-D	21,300				2,130		10,650			21,300
S7-E-Upper	9,100				910		6,825			9,100
S7-E-Middle	3,300				330		2,475			3,300
S7-E-Lower	5,900				590		4,425			5,900
S7-F-Upper	22,000				2,200		16,500			22,000
S7-F-Middle	15,300				1,530		11,475			15,300
S7-F-Lower	3,700				370		2,775			3,700
S7-G	40,000				4,000		40,000			
S7-H	9,300				930		9,300			
S7-I	42,916				4,292		42,916			
S7-J	24,400				2,440		12,200			
S4-South	28,000							14,000	14,000	
S4-West	21,000							15,750	5,250	
S4-North	26,000							13,000	13,000	
S6-South	28,000							14,000	14,000	
S6-West-lower	21,000							15,750	5,250	
S6-West-upper	6,000							4,500	1,500	
S9-G	40,000								40,000	

S9-H	9,300								9,300	
S9-I	42,916								42,916	
S10	41,417								41,417	
S11	15,300							7,650	7,650	
S12	3,300						825		2,475	

Assignment (dimension and extent) of the remediation measures (figure 2-1 to 2-9) for each reach are graphically presented in figure 2-10A through 2-29B. Also shown in these figure are the 20-foot landside and 15-foot waterside O&M corridors. The outer most limits of the O&M corridors define the project ROW. The heights of new levee segments (shown in figure 2-21A to 2-23B for Ring and J levee segments defined in table 2-2) were based on hydraulic design recommendations (enclosure 3, Design of New Levee Segments).

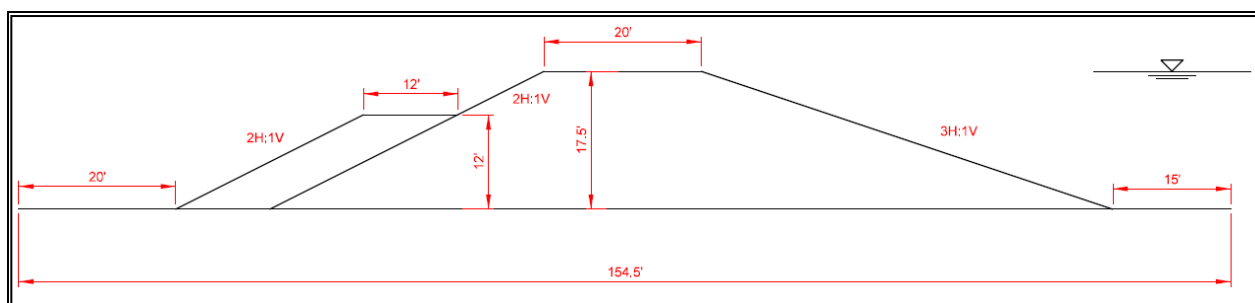


Figure 2-10A – Reach S5-A (Improvement Type 4 for 25% of Reach Length)

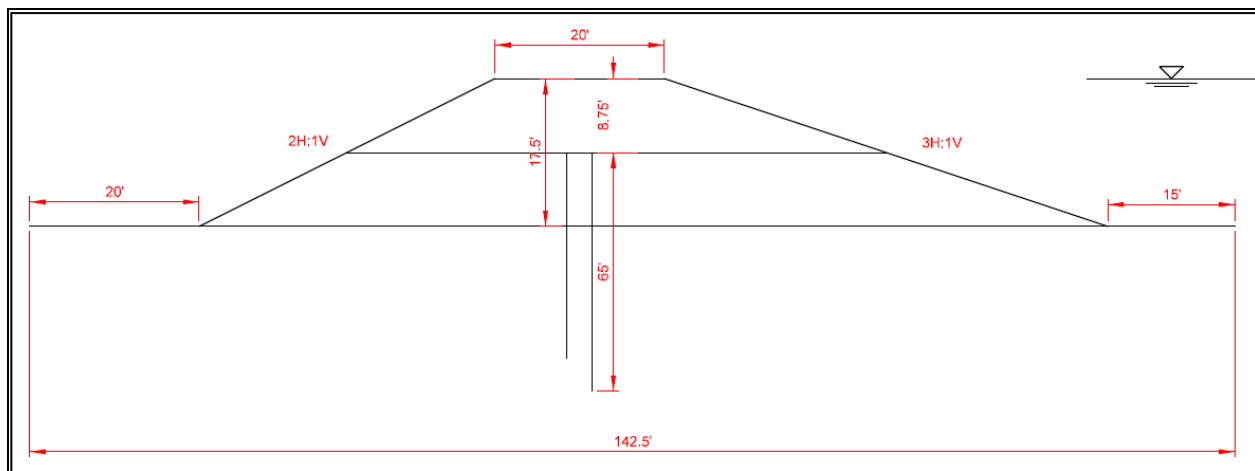


Figure 2-10B – Reach S5-A (Improvement Type 6 for 100% of Reach Length)

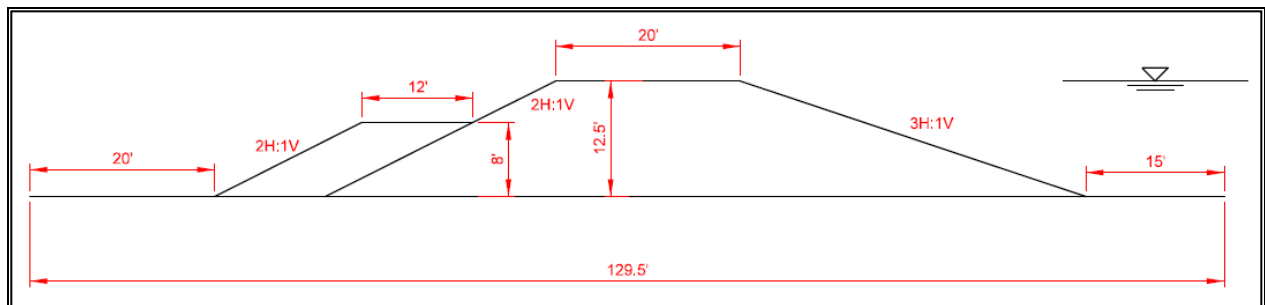


Figure 2-11A – Reach S5-B (Improvement Type 4 for 75% of Reach Length)

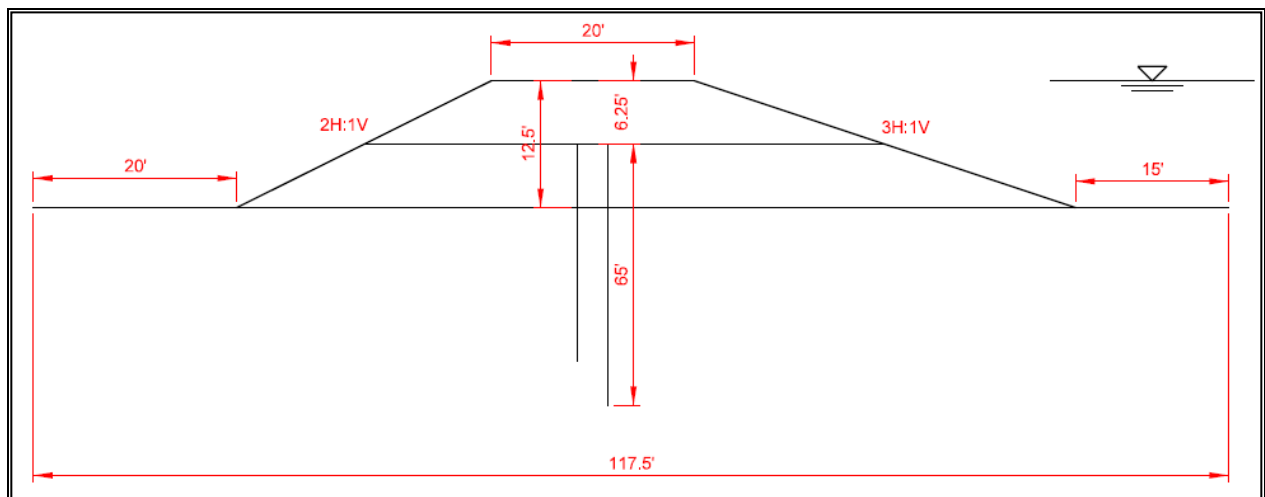


Figure 2-11B – Reach S5-B (Improvement Type 6 for 75% of Reach Length)

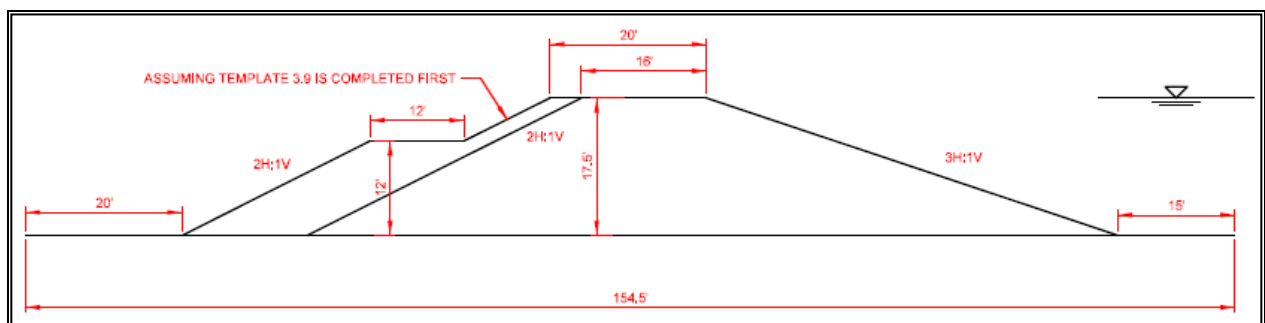


Figure 2-12A – Reach S5-C (Improvement Type 4 for 25% of Reach Length)

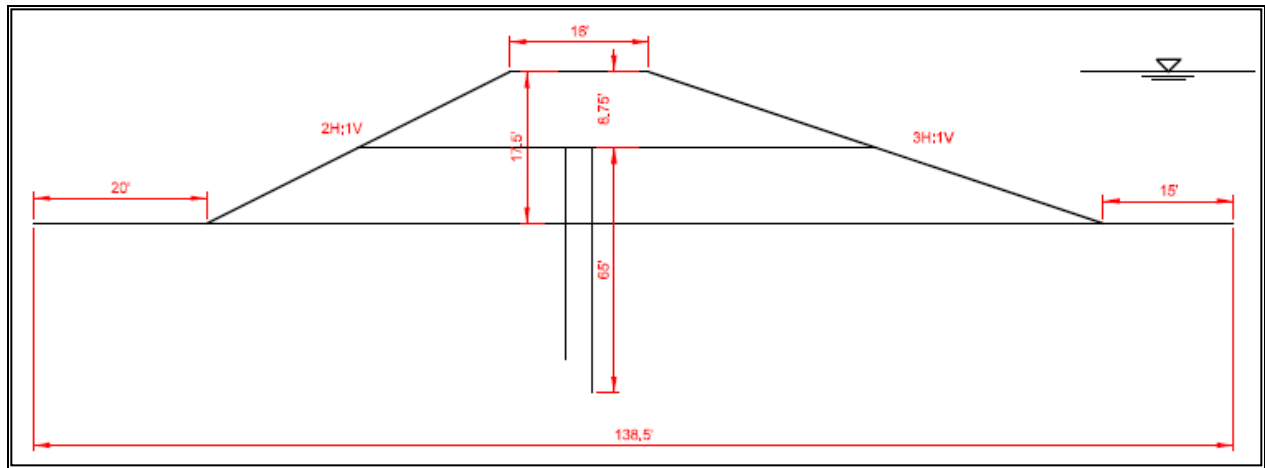


Figure 2-12B – Reach S5-C (Improvement Type 6 for 75% of Reach Length)

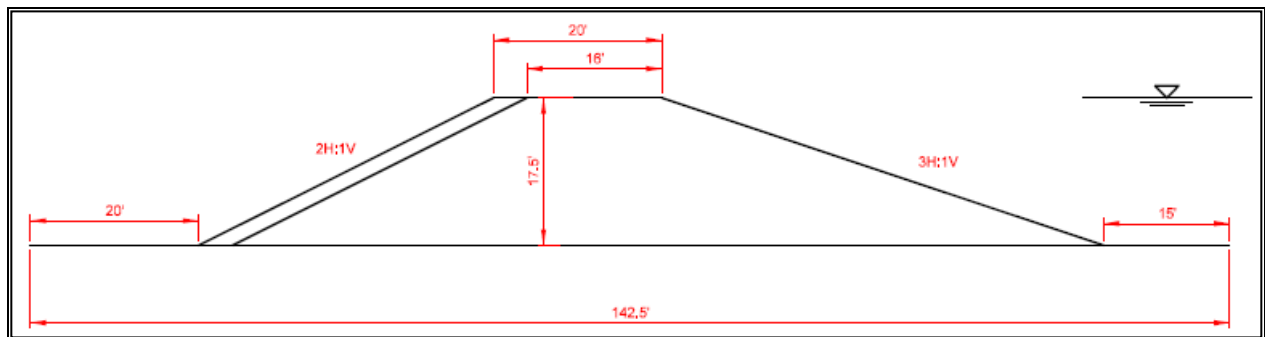


Figure 2-12C – Reach S5-C (Improvement Type 9 for 100% of Reach Length)

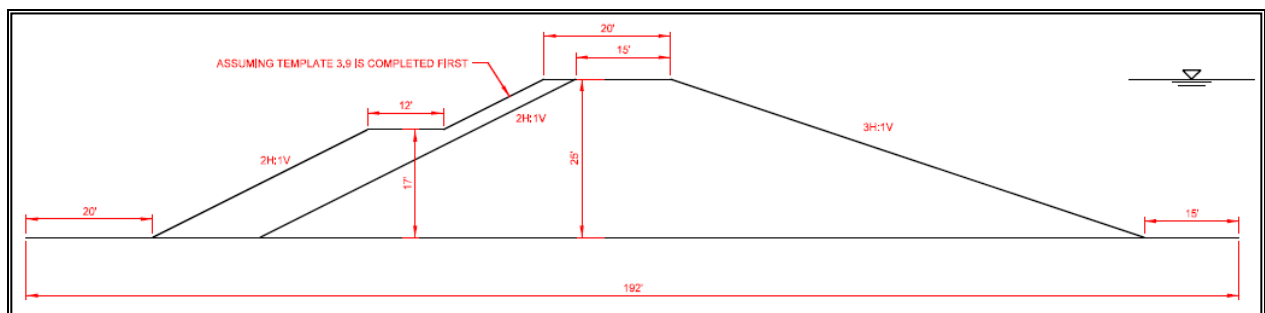


Figure 2-13A – Reach S5-D (Improvement Type 4 for 10% of Reach Length)

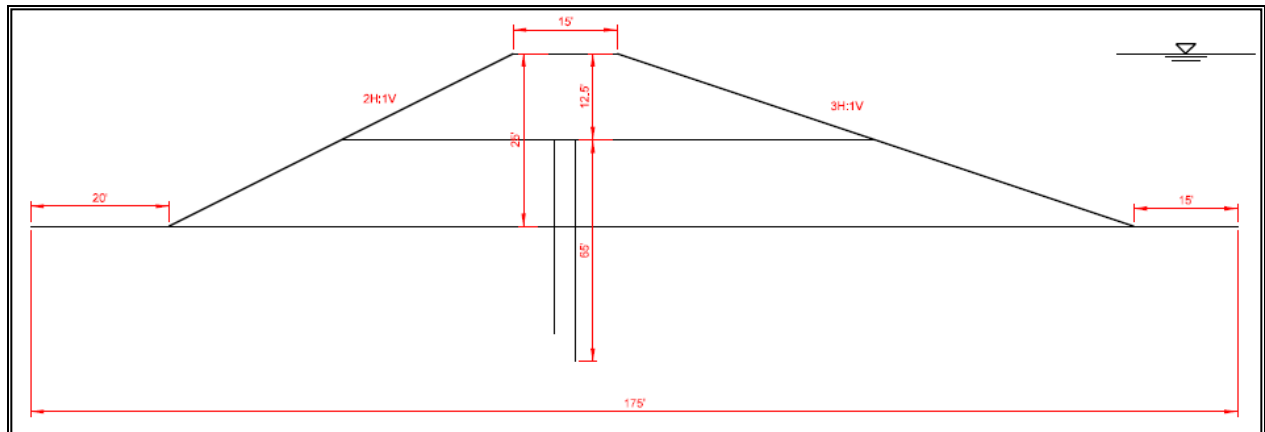


Figure 2-13B – Reach S5-D (Improvement Type 6 for 50% of Reach Length)

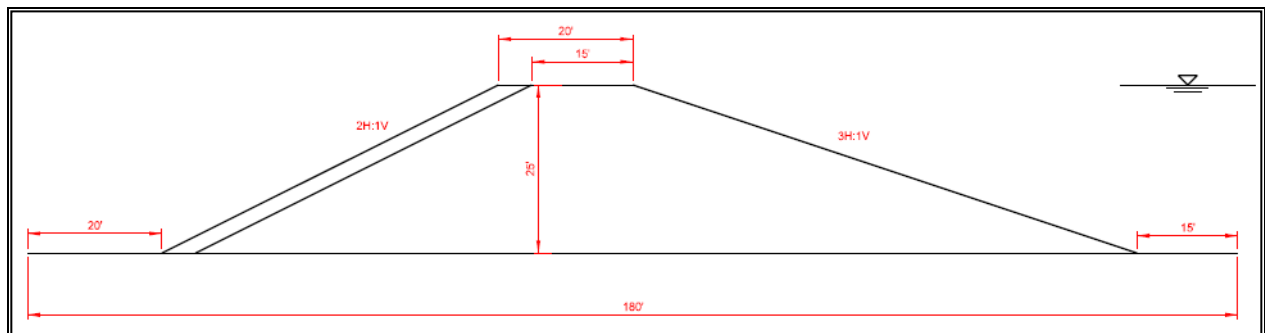


Figure 2-13C – Reach S5-D (Improvement Type 9 for 100% of Reach Length)

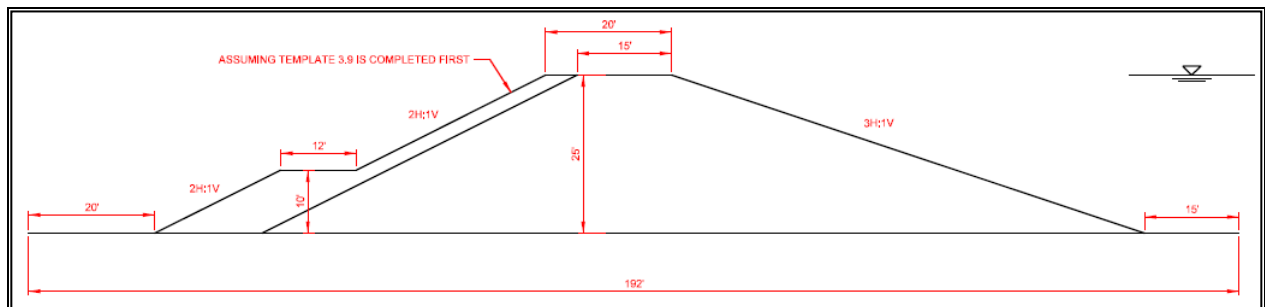


Figure 2-14A – Reach S7-D (Improvement Type 4 for 10% of Reach Length)

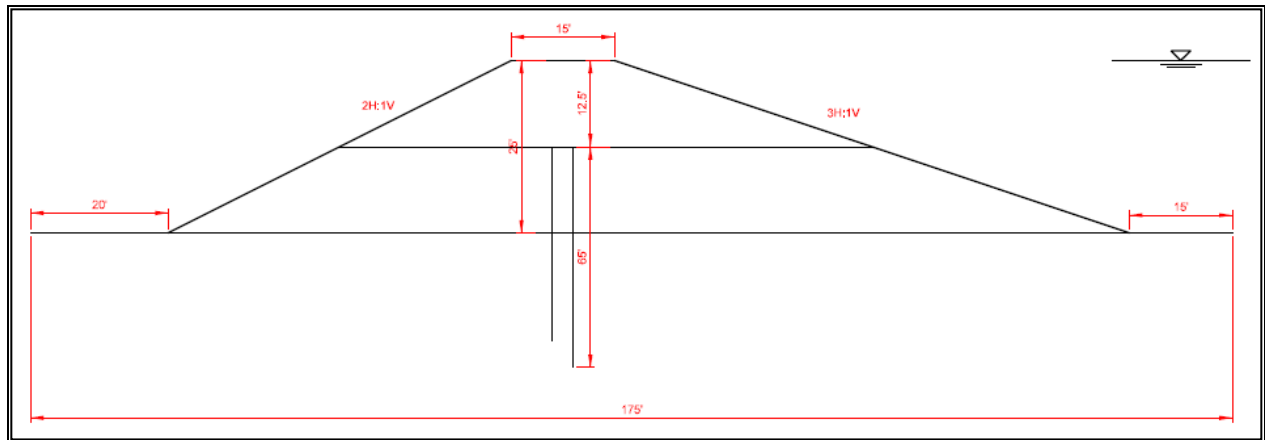


Figure 2-14B – Reach S7-D (Improvement Type 6 for 50% of Reach Length)

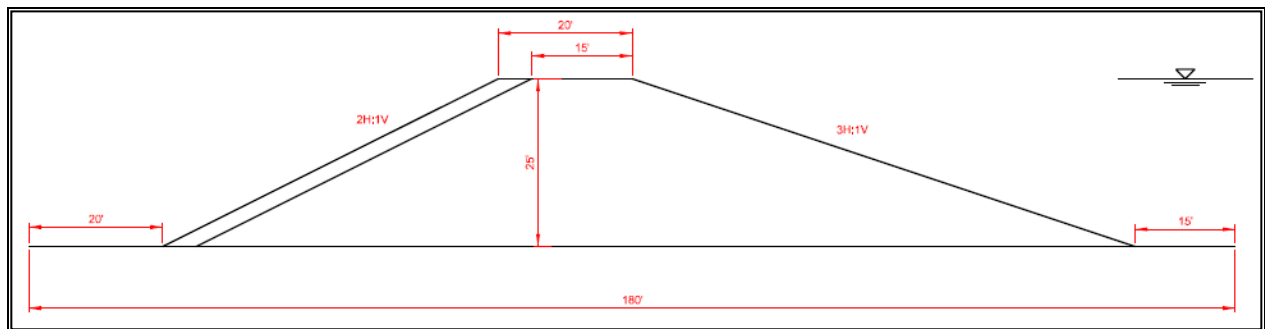


Figure 2-14C – Reach S7-D (Improvement Type 9 for 100% of Reach Length)

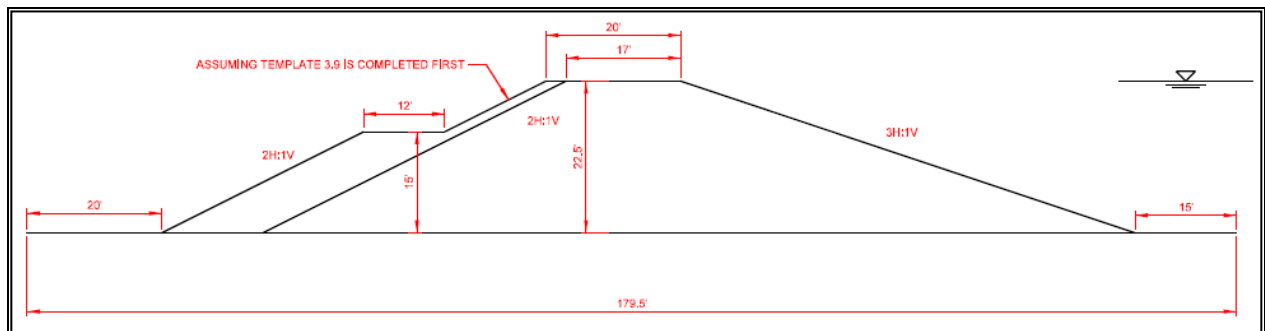


Figure 2-15A – Reach S7-E (Improvement Type 4 for 10% of Reach Length)

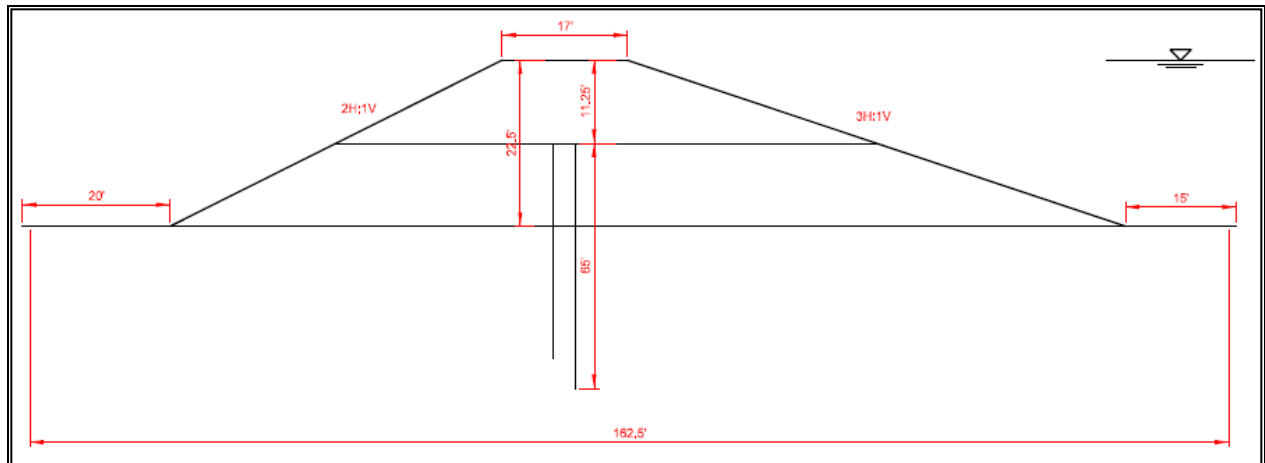


Figure 2-15B – Reach S7-E (Improvement Type 6 for 75% of Reach Length)

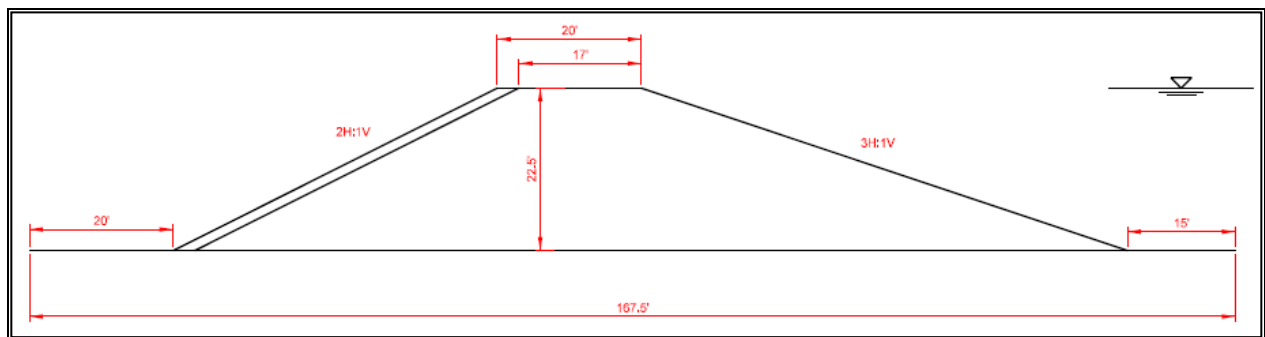


Figure 2-15C – Reach S7-E (Improvement Type 9 for 100% of Reach Length)

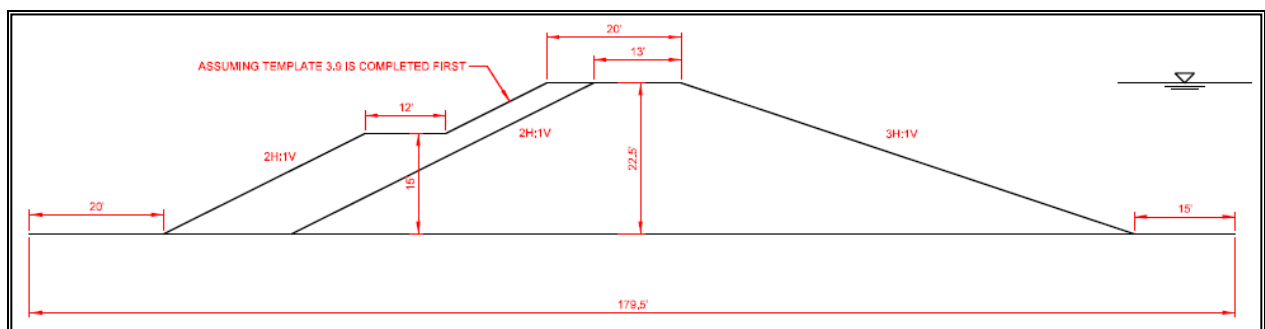


Figure 2-16A – Reach S7-F (Improvement Type 4 for 10% of Reach Length)

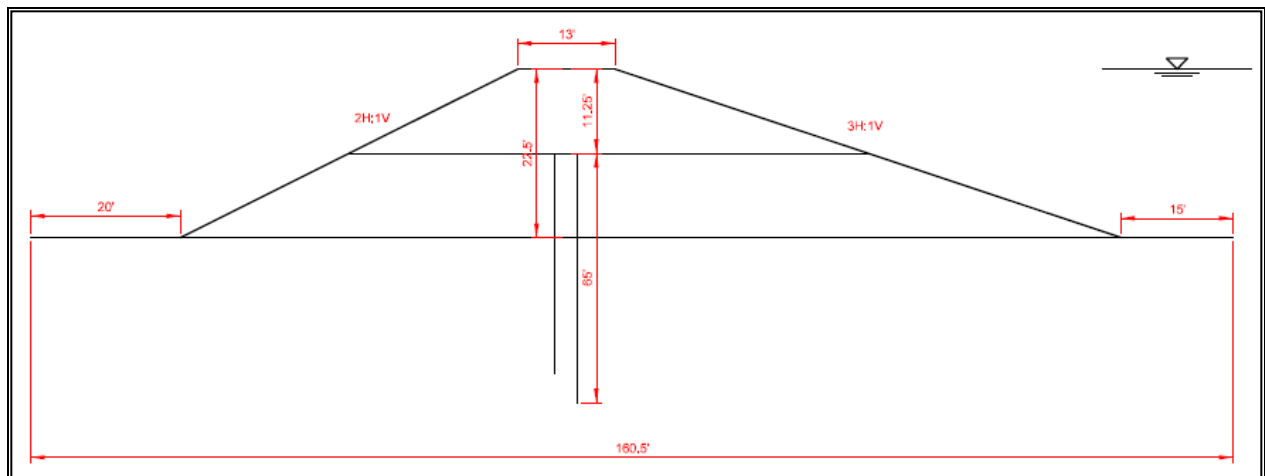


Figure 2-16B – Reach S7-F (Improvement Type 6 for 75% of Reach Length)

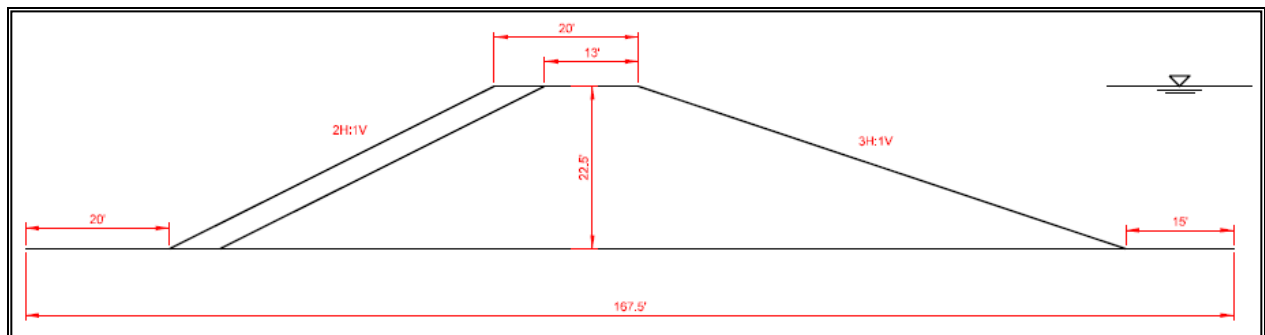


Figure 2-16C – Reach S7-F (Improvement Type 9 for 100% of Reach Length)

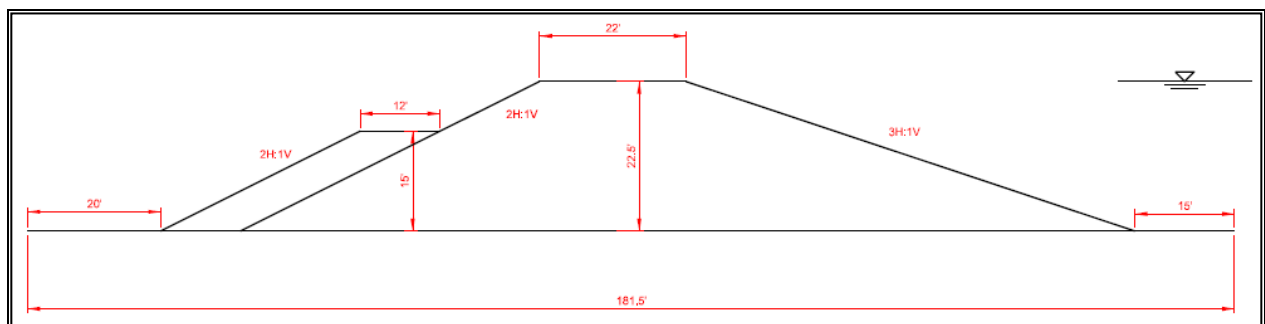


Figure 2-17A – Reach S7-G (Improvement Type 4 for 10% of Reach Length)

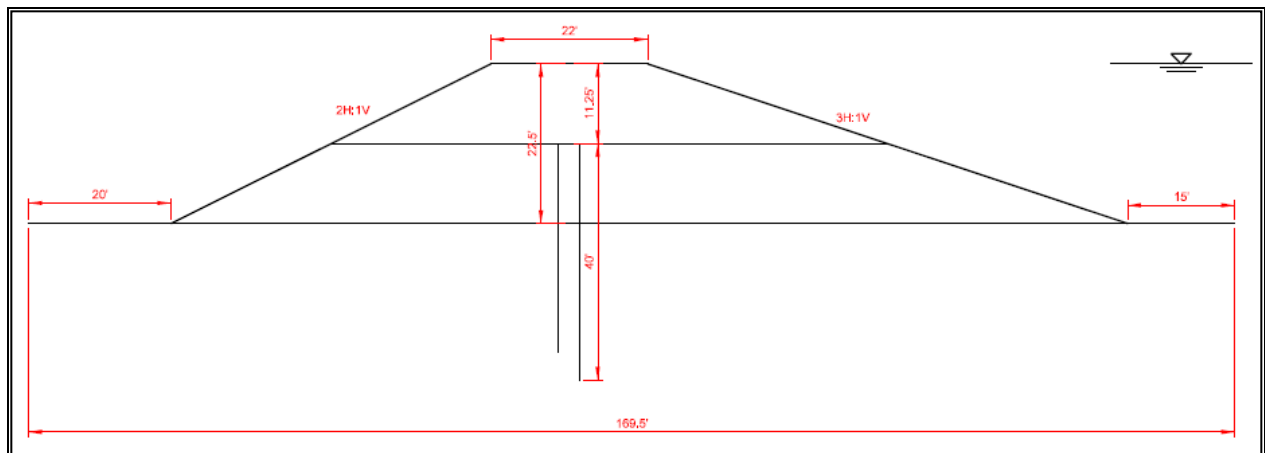


Figure 2-17B – Reach S7-G (Improvement Type 6 for 100% of Reach Length)

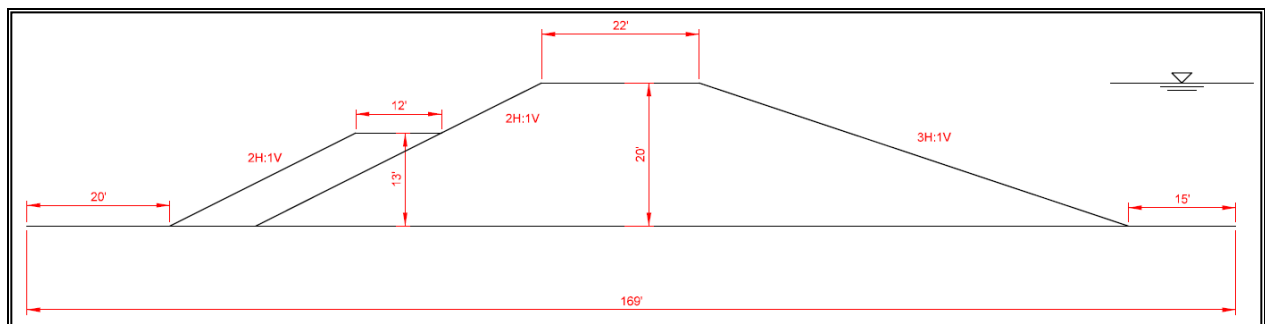


Figure 2-18A – Reach S7-H (Improvement Type 4 for 10% of Reach Length)

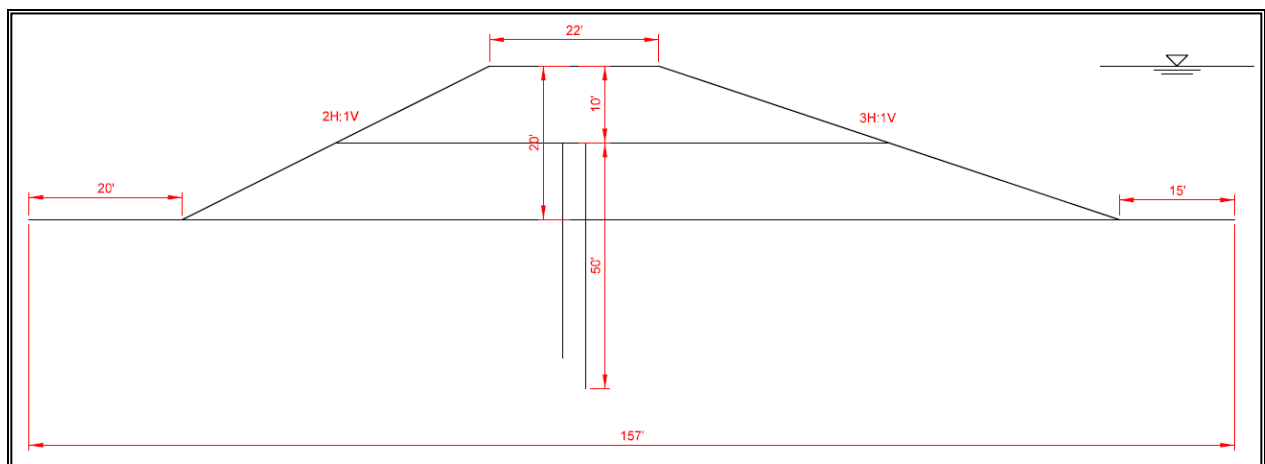


Figure 2-18B – Reach S7-H (Improvement Type 6 for 100% of Reach Length)

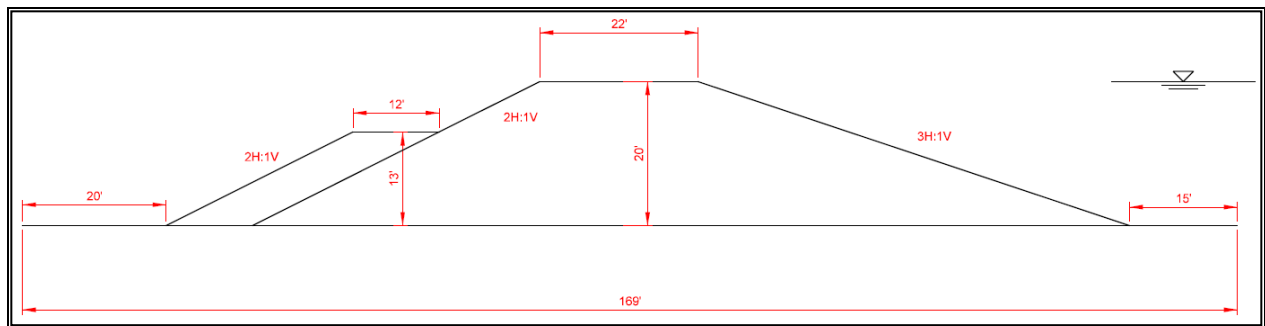


Figure 2-19A – Reach S7-I (Improvement Type 4 for 10% of Reach Length)

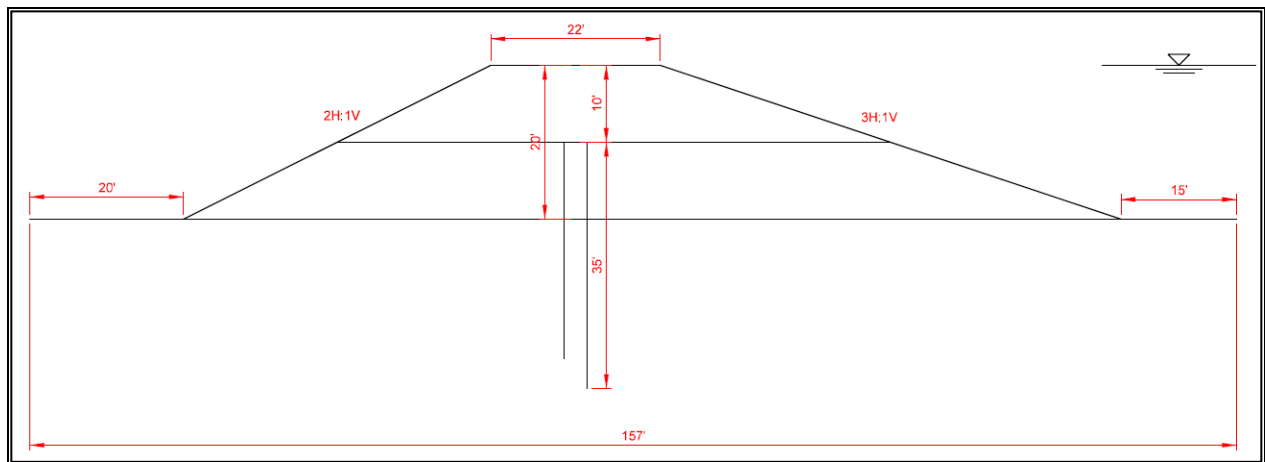


Figure 2-19B – Reach S7-I (Improvement Type 6 for 100% of Reach Length)

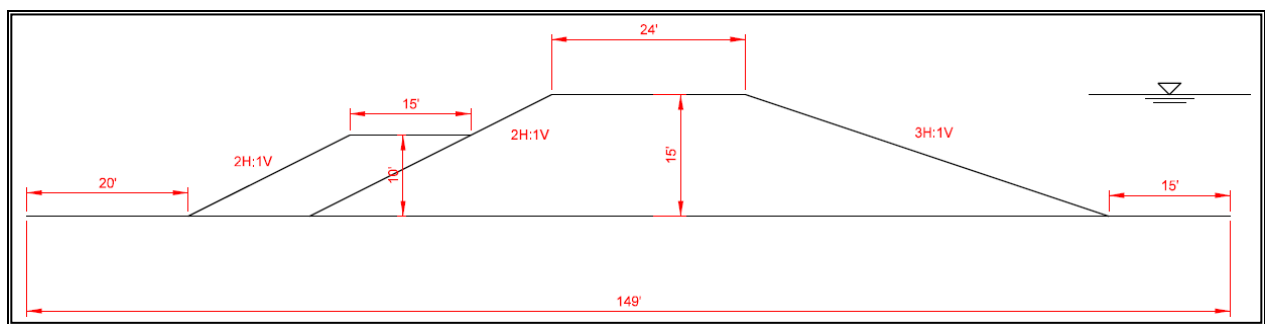


Figure 2-20A – Reach S7-J (Improvement Type 4 for 10% of Reach Length)

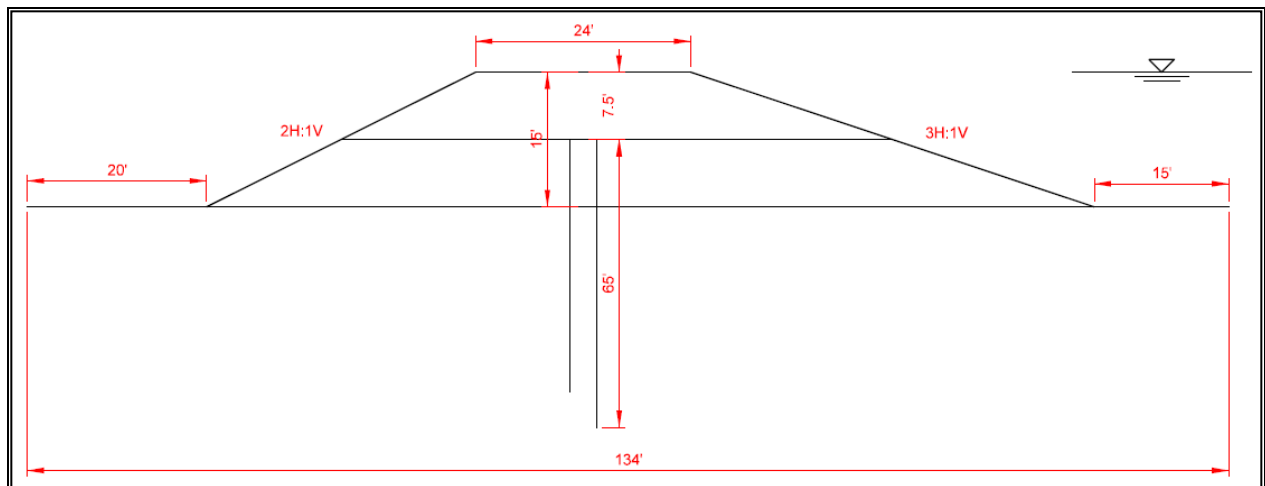


Figure 2-20B – Reach S7-J (Improvement Type 6 for 50% of Reach Length)

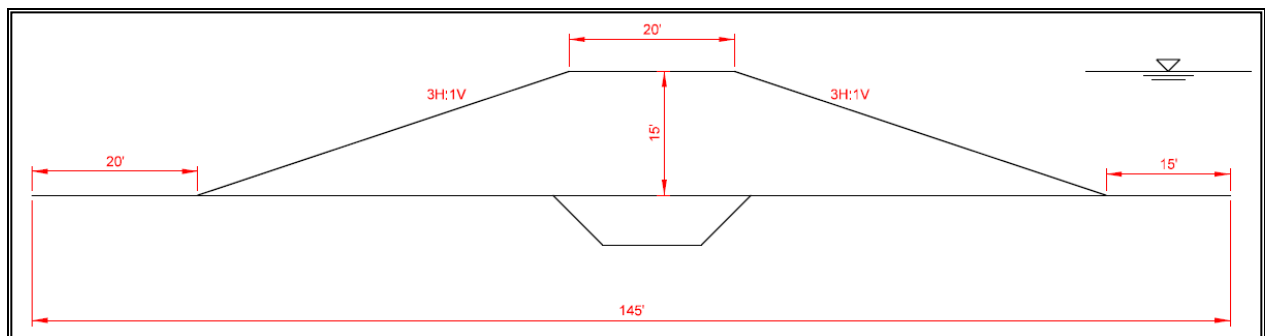


Figure 2-21A – Reach S4-South/S6-South (Improvement Type 7 for 50% of Reach Length)

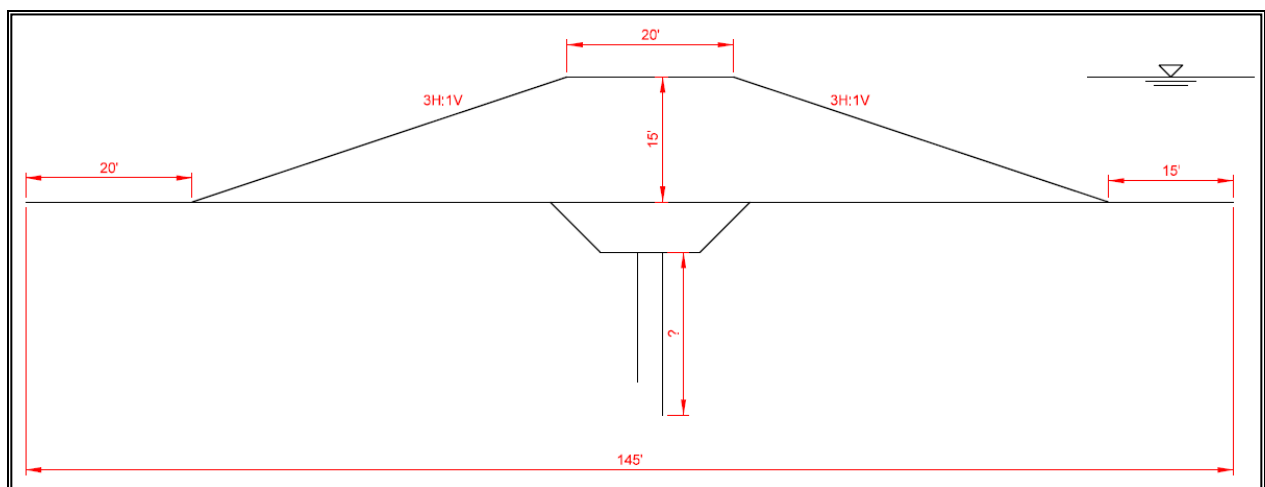


Figure 2-21B – Reach S4-South/S6-South (Improvement Type 8 for 50% of Reach Length)

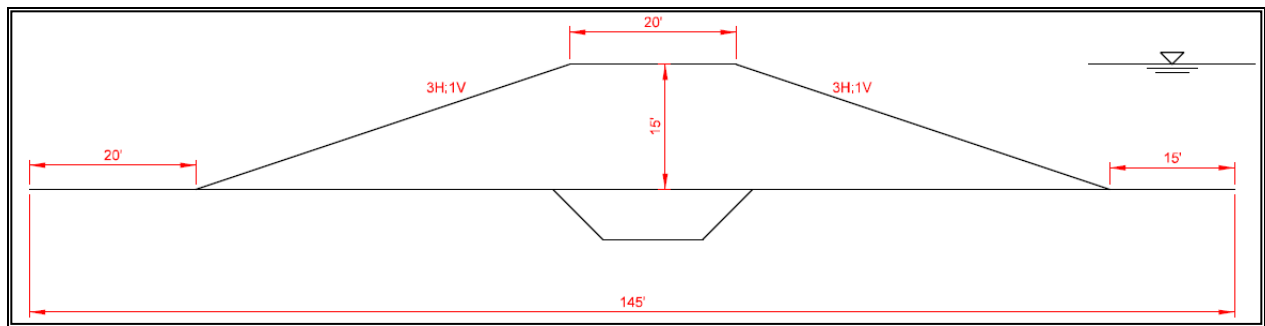


Figure 2-22A – Reach S4-West/S6-West (Improvement Type 7 for 75% of Reach Length)

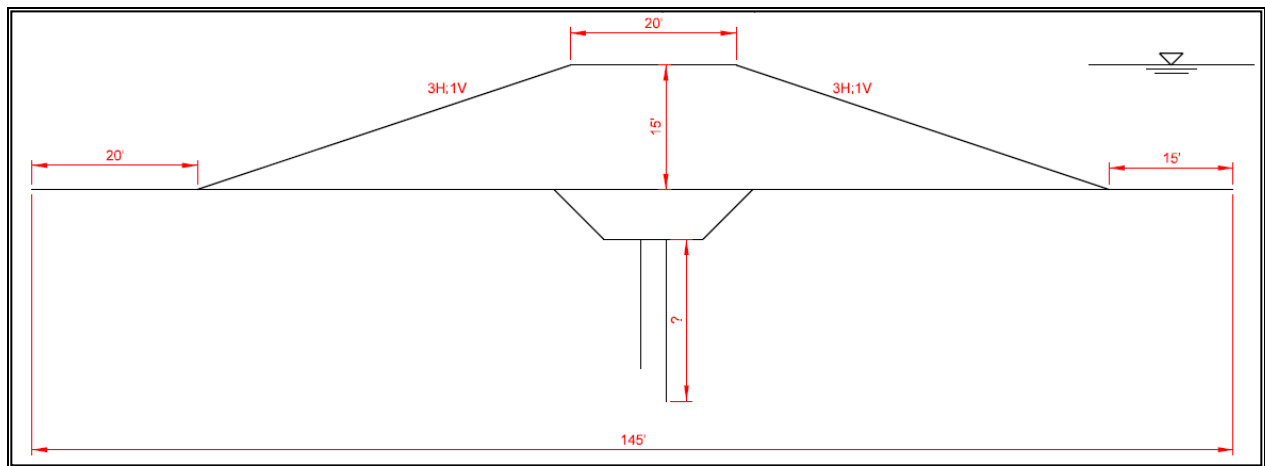


Figure 2-22B – Reach S4-West/S6-West (Improvement Type 8 for 25% of Reach Length)

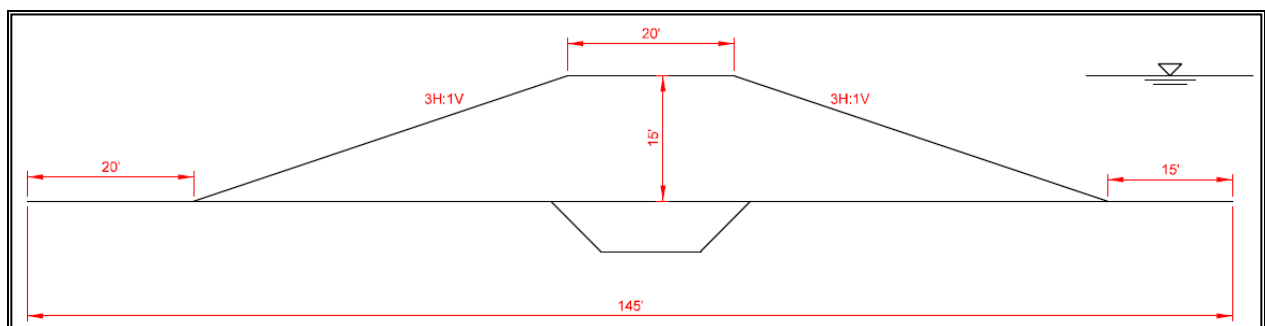


Figure 2-23A – Reach S4-North (Improvement Type 7 for 50% of Reach Length)

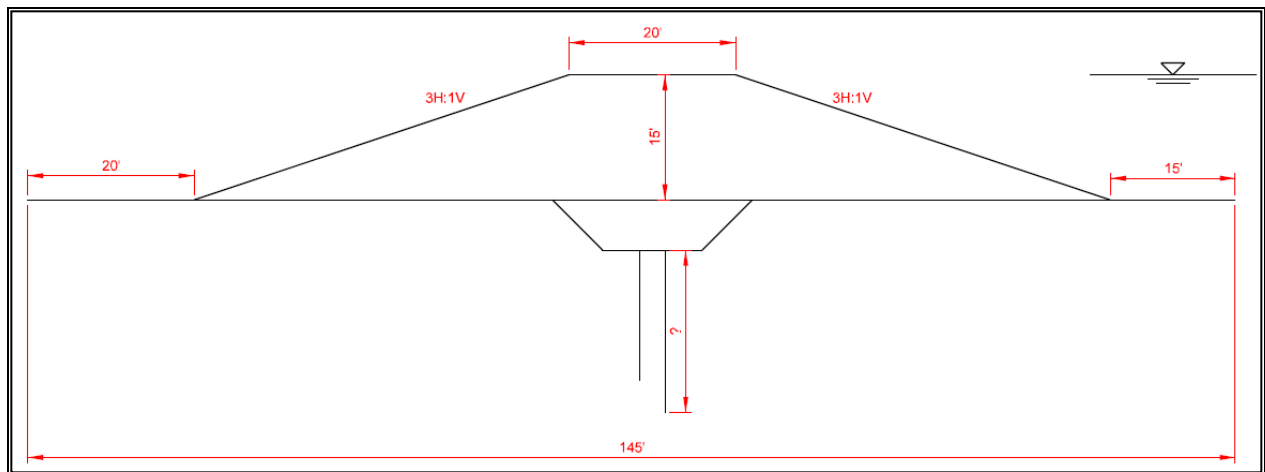


Figure 2-23B – Reach S4-North (Improvement Type 8 for 50% of Reach Length)

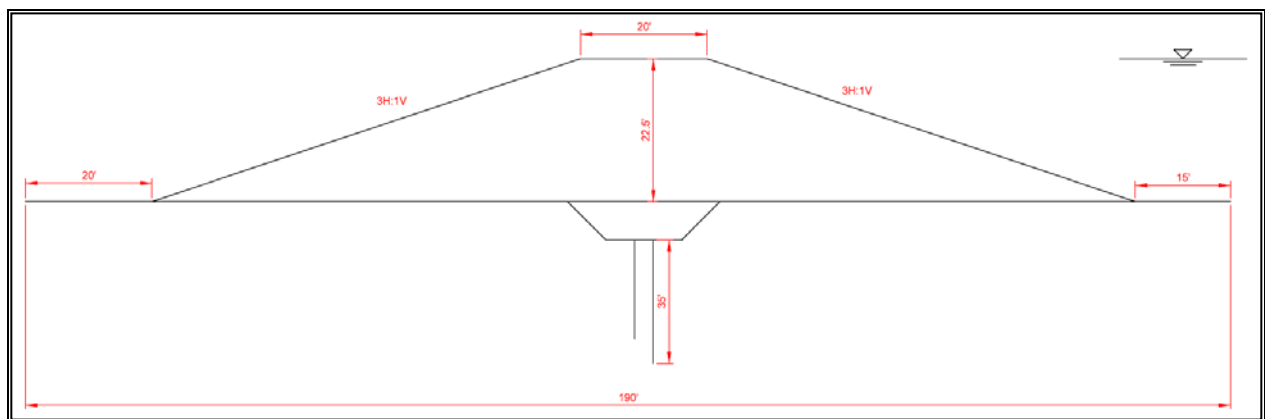


Figure 2-24 – Reach S9-G (Improvement Type 8 for 100% of Reach Length)

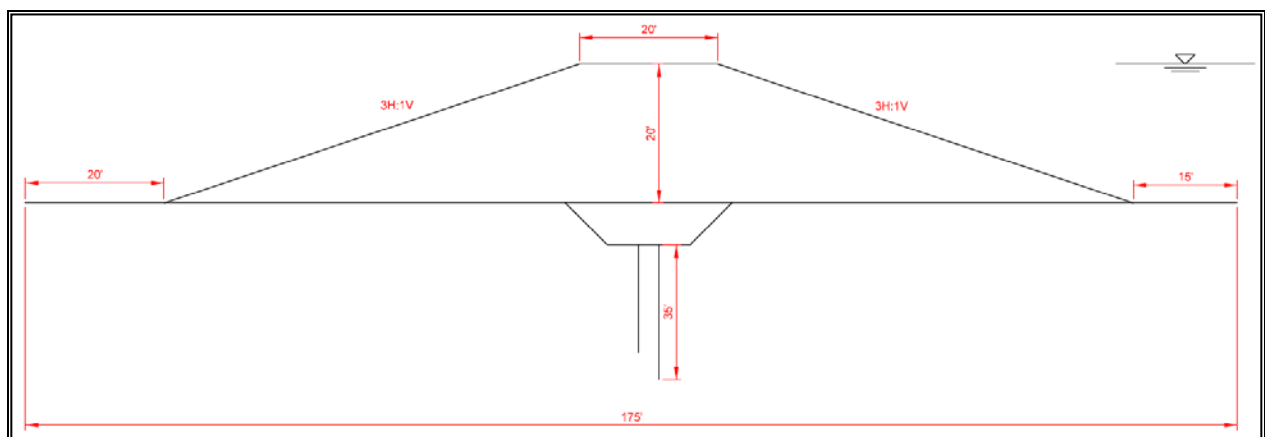


Figure 2-25 – Reach S9-H (Improvement Type 8 for 100% of Reach Length)

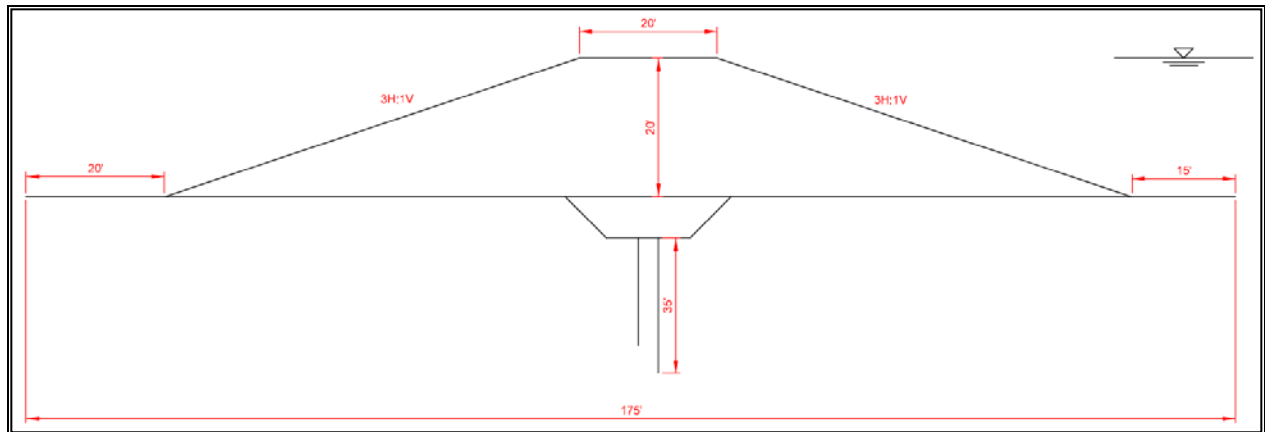


Figure 2-26 – Reach S9-I (Improvement Type 8 for 100% of Reach Length)

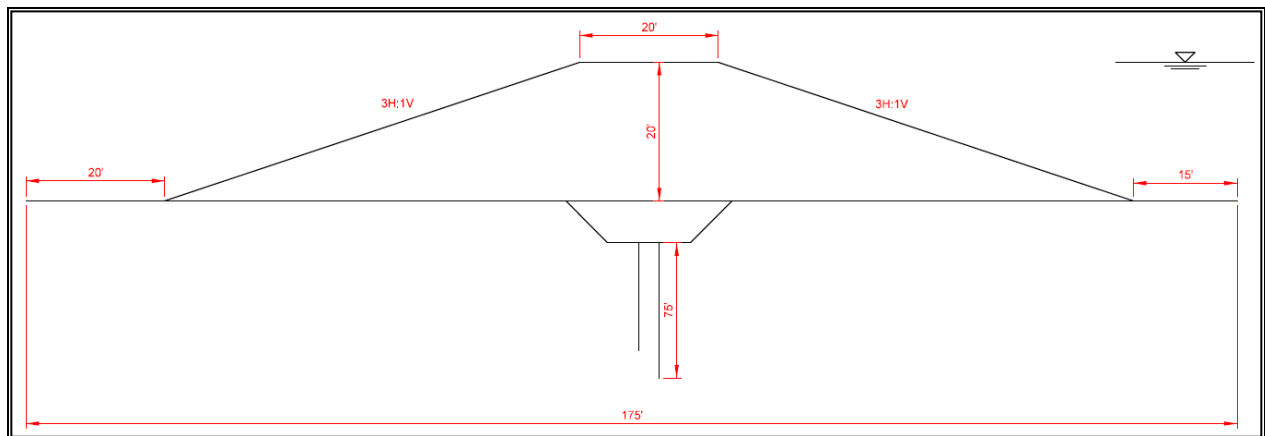


Figure 2-27 – Reach S10 (Improvement Type 8 for 100% of Reach Length)

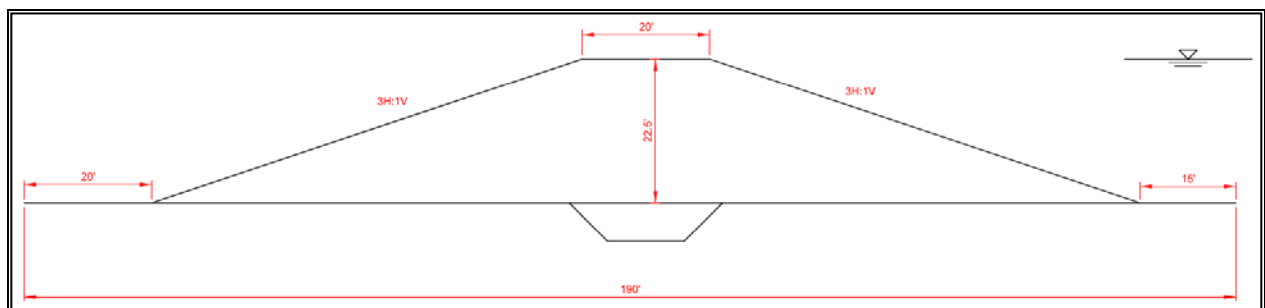


Figure 2-28A – Reach S11 (Improvement Type 7 for 50% of Reach Length)

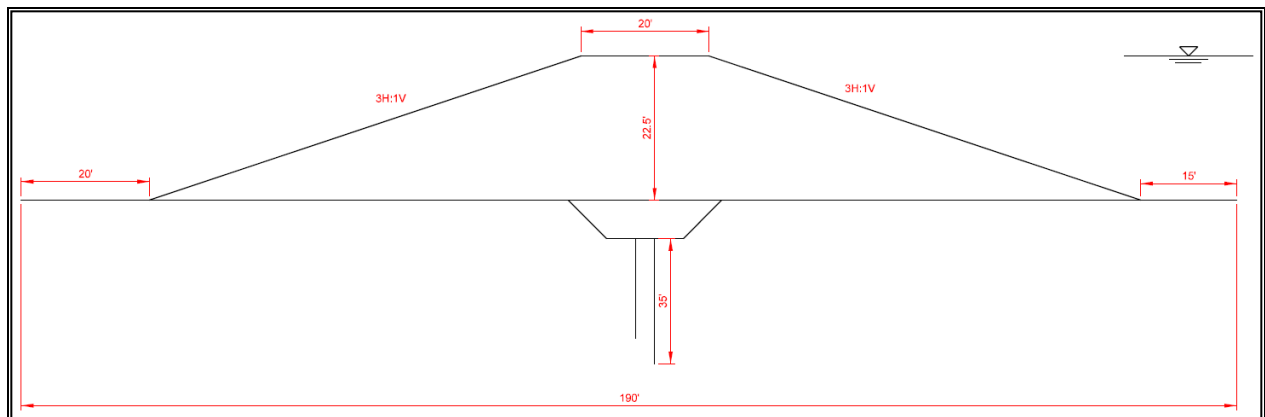


Figure 2-28B – Reach S11 (Improvement Type 8 for 50% of Reach Length)

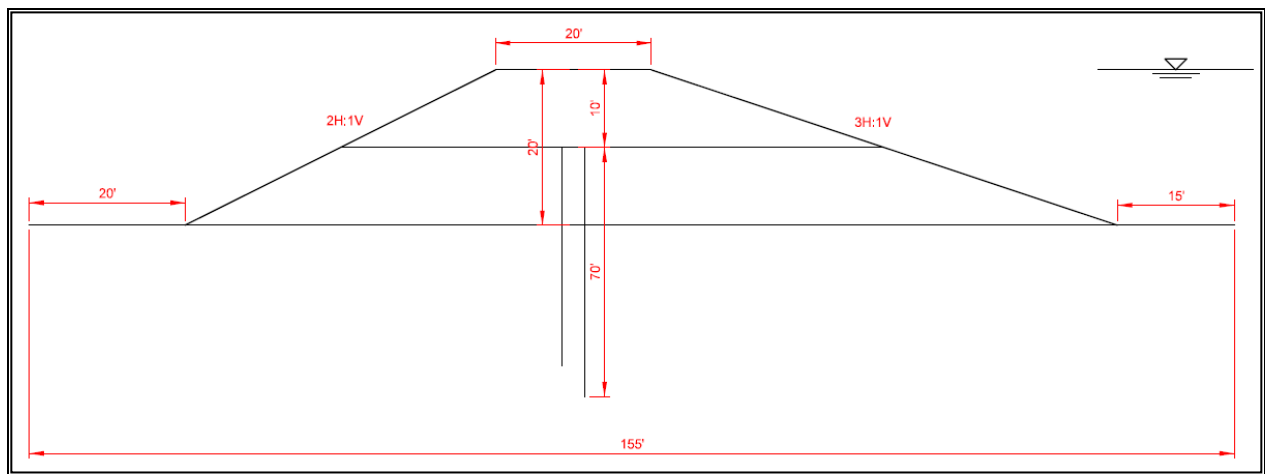


Figure 2-29A – Reach S12 (Improvement Type 6 for 25% of Reach Length)

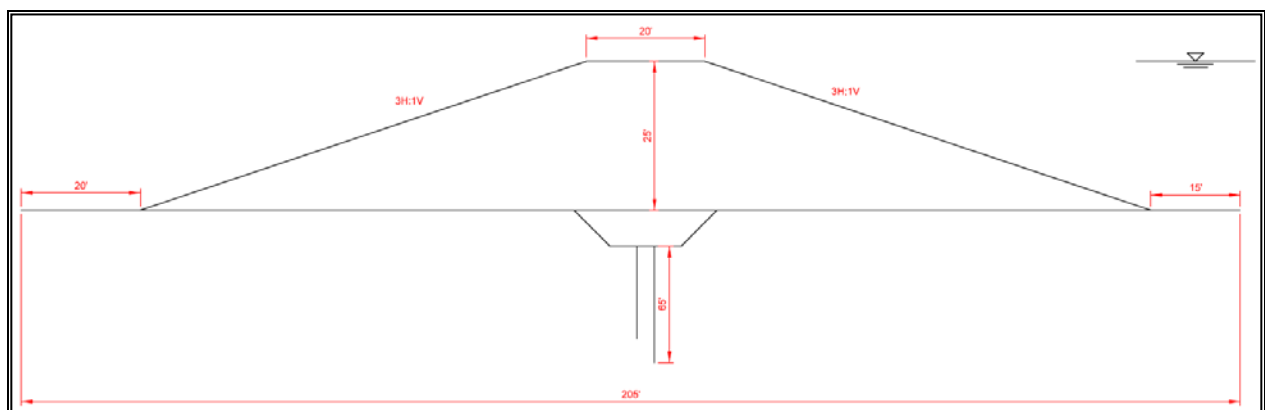


Figure 2-29B – Reach S12 (Improvement Type 8 for 75% of Reach Length)

2.5 Encroachments

The utilities (pipelines and conduits only) located within the proposed ROW for new levee segments (e.g. setback levees and ring levee segments) were not specifically addressed during this phase of the study and estimated as a lump sum percentage of the total utility cost. Physical structures located within the proposed ROW, roads and canals crossing the alignment of new levee segments were specifically addressed during this phase. New levee segments were defined in table 2-2 and shown in figure 1-1 of section 2.3.1.

A comprehensive inventory of all encroachments (utilities, physical structures and woody vegetations) located within the proposed ROW of the existing levee segments (see figure 2-10A to 2-20B) was completed based on existing data and field investigations. The existing encroachment data came from multiple sources including the CVFPB encroachment list, the USACE Periodic Inspection report and as-built of various projects located along the FRWL alignment. Field investigations were conducted to validate and improve the existing inventories.

The final encroachment list (enclosure 4, Encroachment Improvements & Estimates) shows numerous pipelines (both gravity and pressurized lines) and conduits (cables, electrical lines etc.) crossing the existing alignments of the FRWL, SBEL and WCEL. The record also indicated a number of utilities running parallel to the alignments (power poles, irrigation ditches, pipelines etc.), physical structures (public, residential and commercial buildings), and woody vegetation (mature trees) currently located within the proposed ROW of the existing levee segments. These encroachments were divided into 12 groups/types.

The following paragraphs outline the approach for addressing each type of encroachment. To avoid interference with construction of other project features, it is assumed that all levee penetrations will be removed prior to levee construction and disposed/replaced after the levee construction is completed. It is also assumed that temporary bypass will be provided at each utility improvement sites to avoid impacts to existing operations. All pipelines and conduits crossing the levee alignment will be modified to include positive closure devices and meet the USACE design criteria for levee penetrations in accordance with EM 1110-2-1913.

Refer to enclosure 4, Encroachment Improvements & Estimates, for the complete inventory, classification and remediation measures for all encroachments located within the proposed ROW of the existing levee segments.

2.5.1 Type 1

This group includes the major utilities those are crossing the levee prism and still in good condition. Relocation of these utility crossings above the DWSE would result in high construction cost and impacts. Therefore, the proposed remediation method is to construct jet grouting cutoff wall around the penetrations.

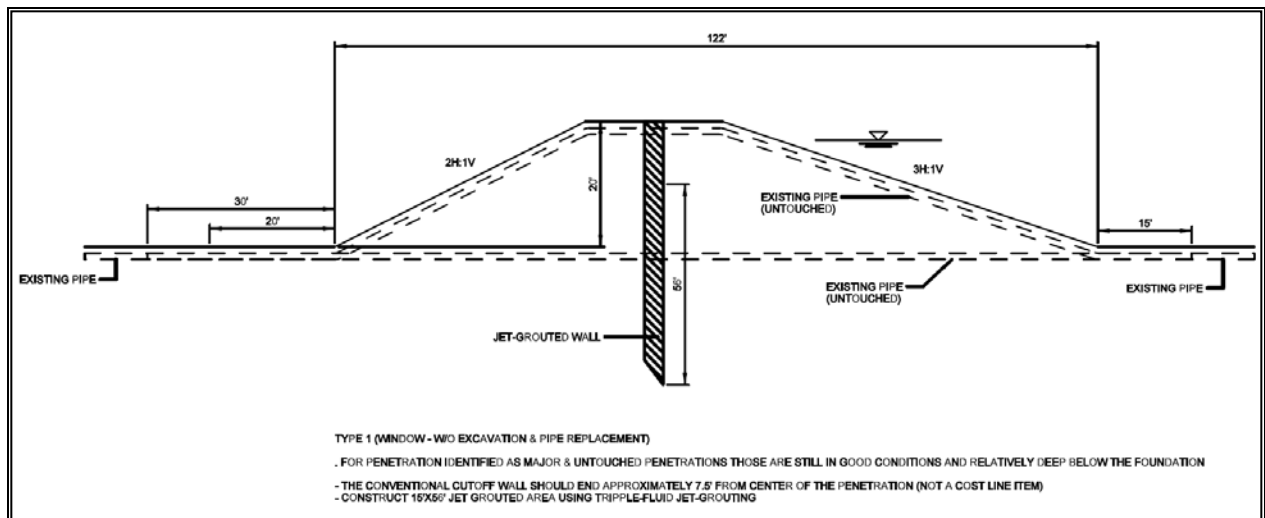


Figure 2-30A – Encroachment Type 1 – Section

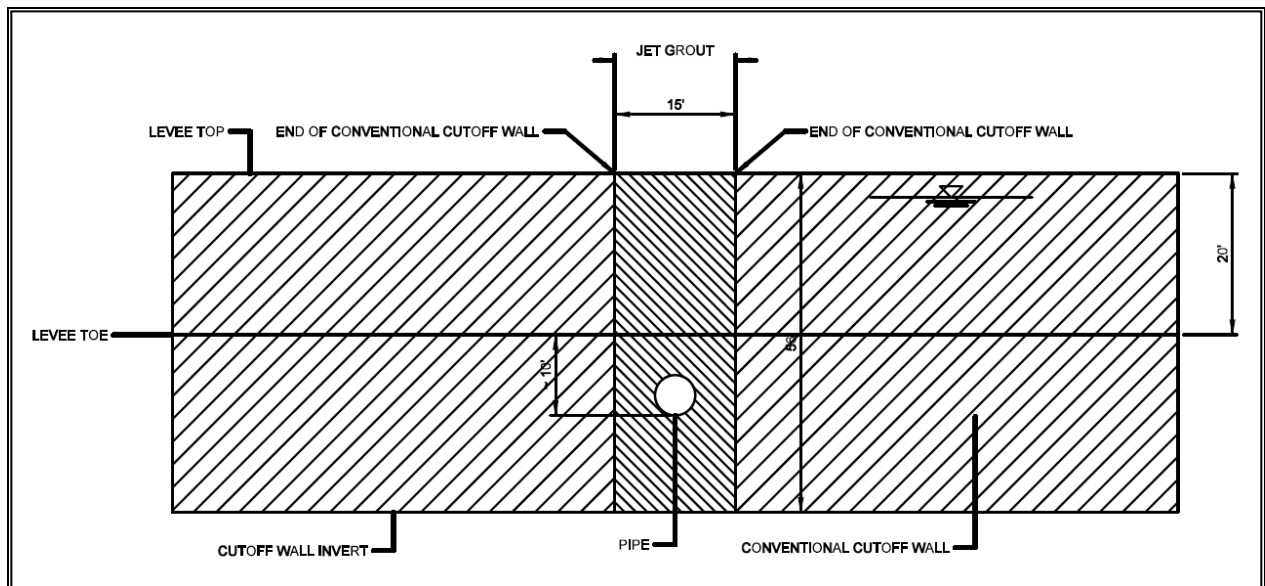


Figure 2-30B – Encroachment Type 1 – Profile

2.5.2 Type 2

This group includes the utilities those are crossing the levee prism (raised and through pipes/conduits) and abandoned. The proposed remediation method is to remove these abandoned penetrations.

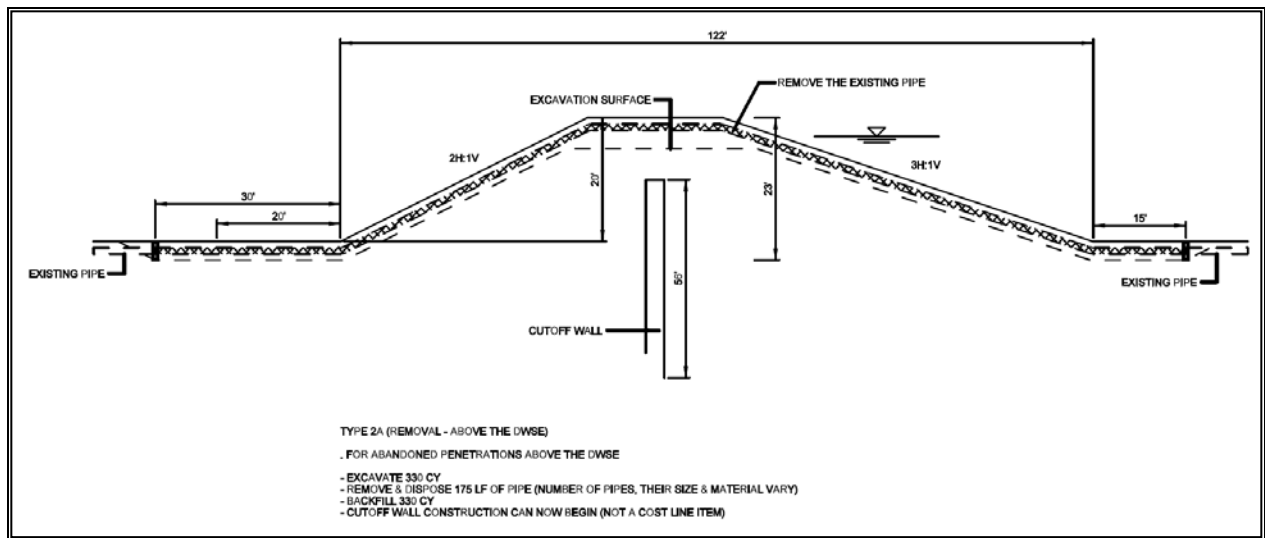


Figure 2-31A – Encroachment Type 2A – Section

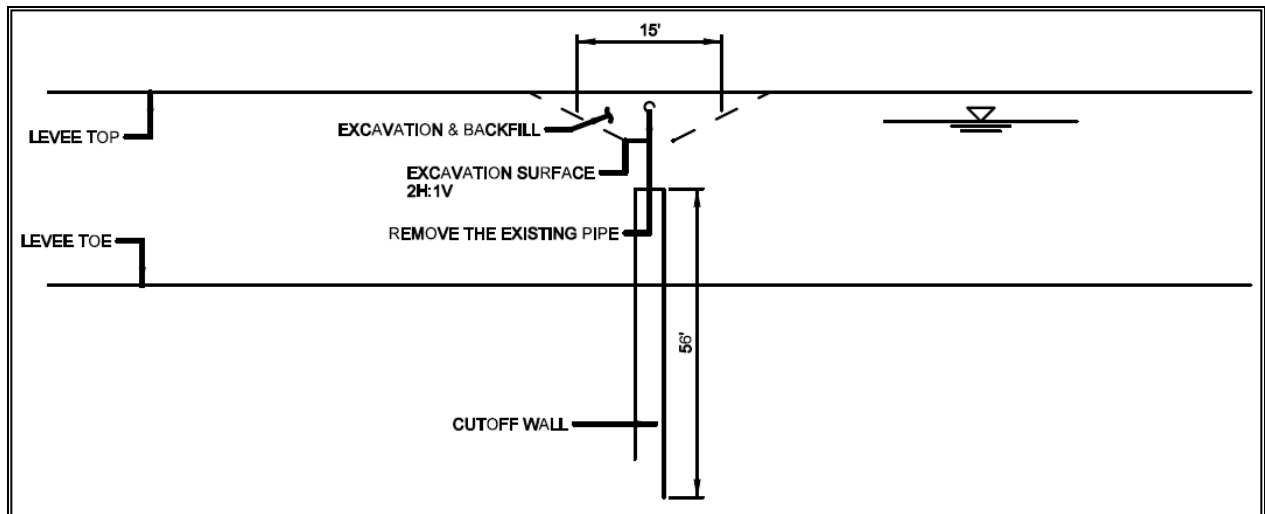


Figure 2-31B – Encroachment Type 2A – Profile

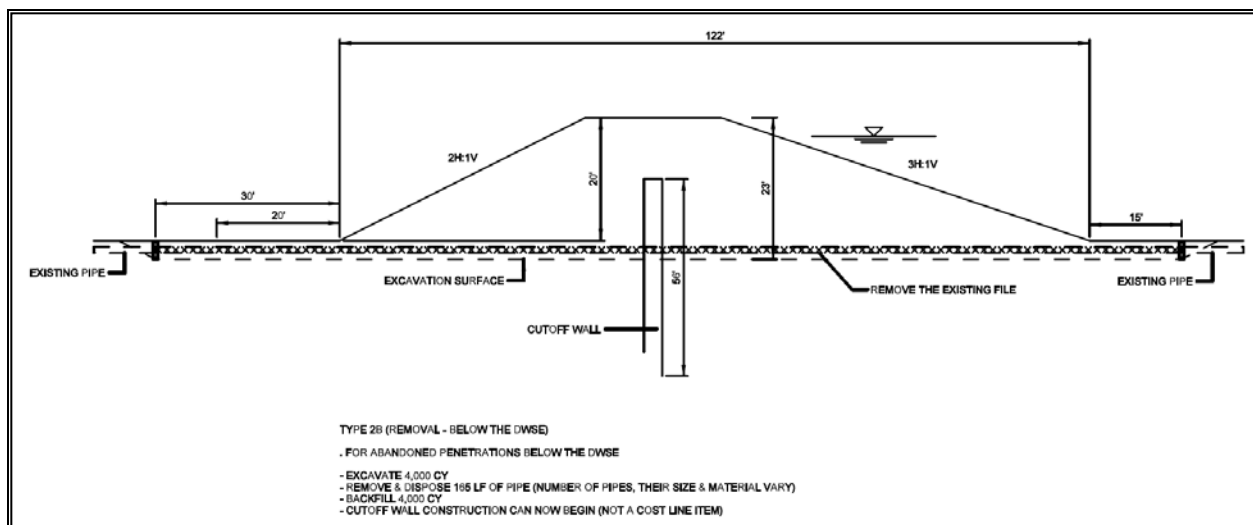


Figure 2-32A – Encroachment Type 2B – Section

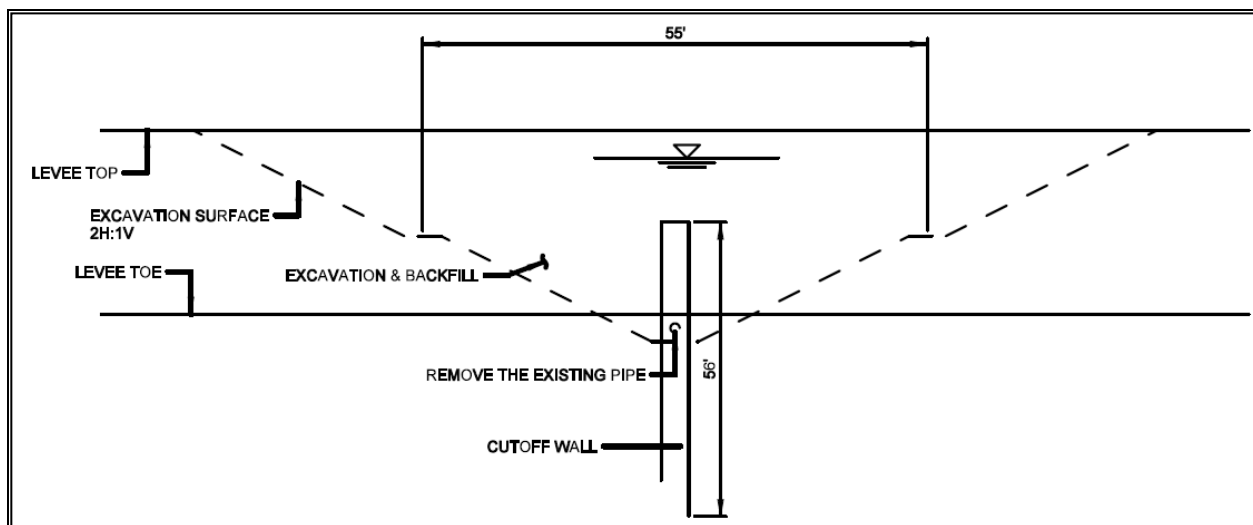


Figure 2-32B – Encroachment Type 2B – Profile

2.5.3 Type 3

This group includes utilities those are crossing the levee prism, dated and don't meet the current standard, include: (1) Communication conduits crossing the levee prism above the DWSE, (2) Minor pressurized pipelines crossing the levee prism above the DWSE, (3) Major pressurized pipelines crossing the levee prism below the DWSE, and (4) Gravity pipelines crossing the levee prism below the DWSE. These pipelines and conduits will be removed (before the cutoff wall construction begins) and replaced in-place (after the cutoff wall construction completes) with proper pipe materials and positive closure devices.

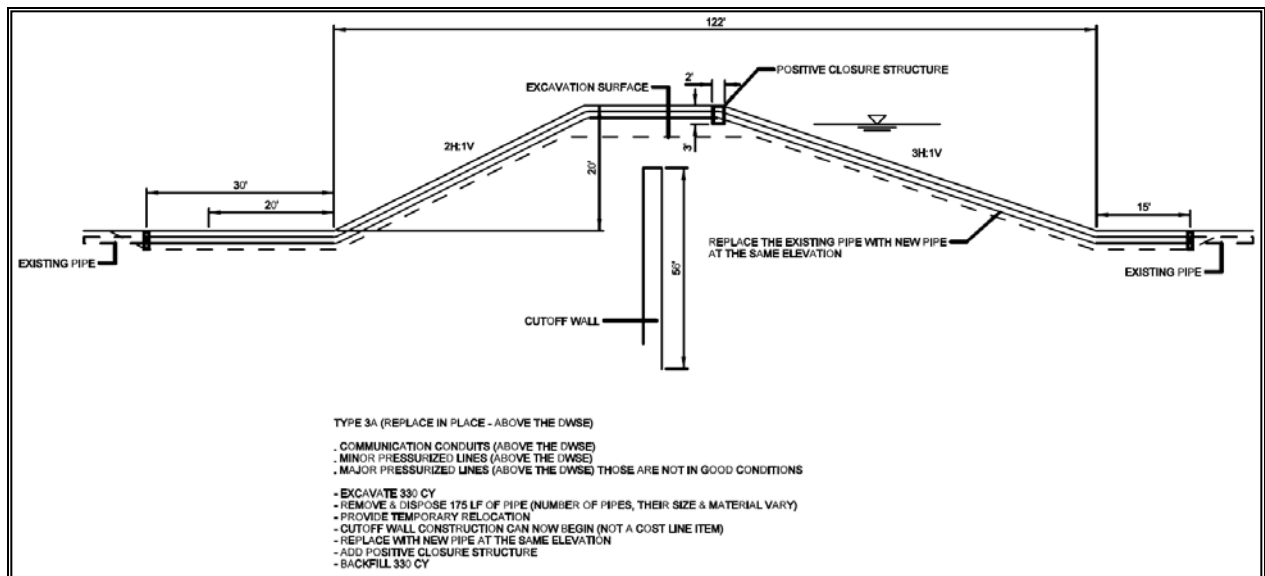


Figure 2-33A – Encroachment Type 3A – Section

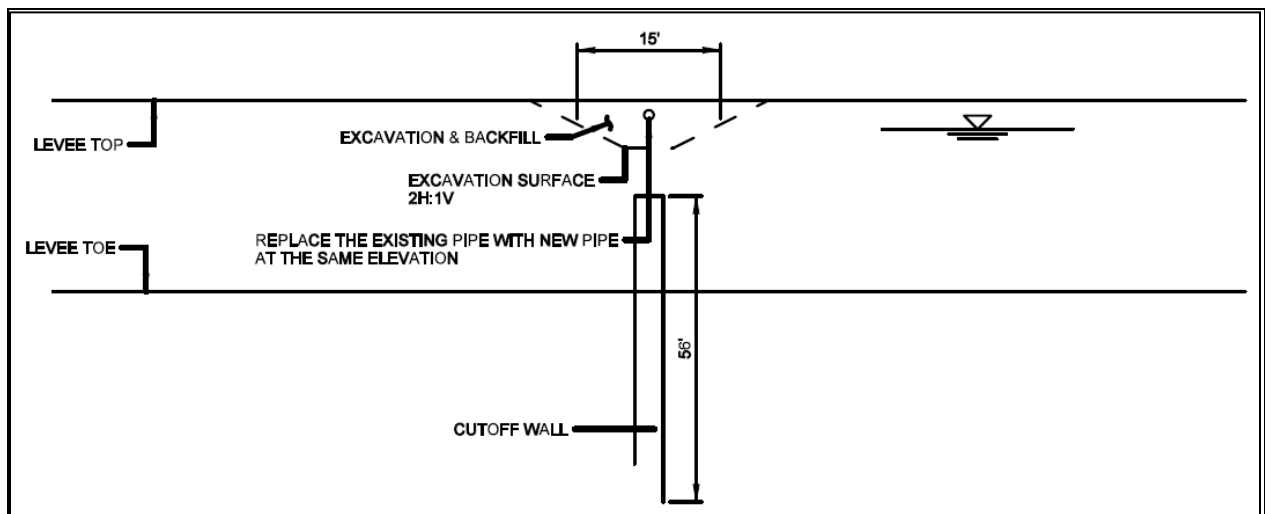


Figure 2-33B – Encroachment Type 3A – Profile

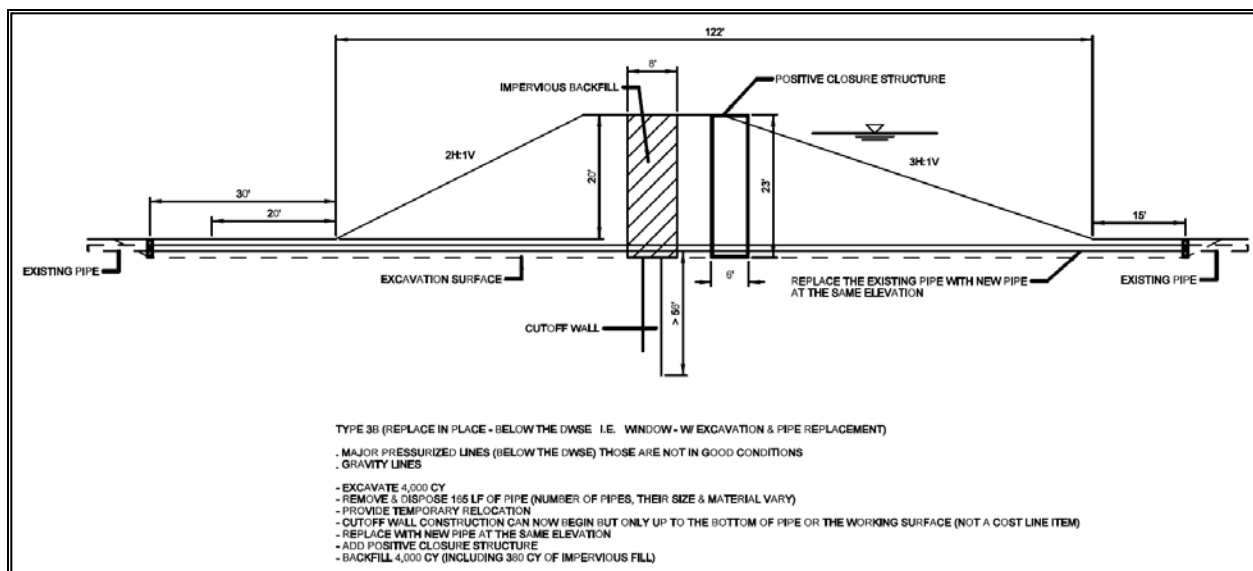


Figure 2-34A – Encroachment Type 3B – Section

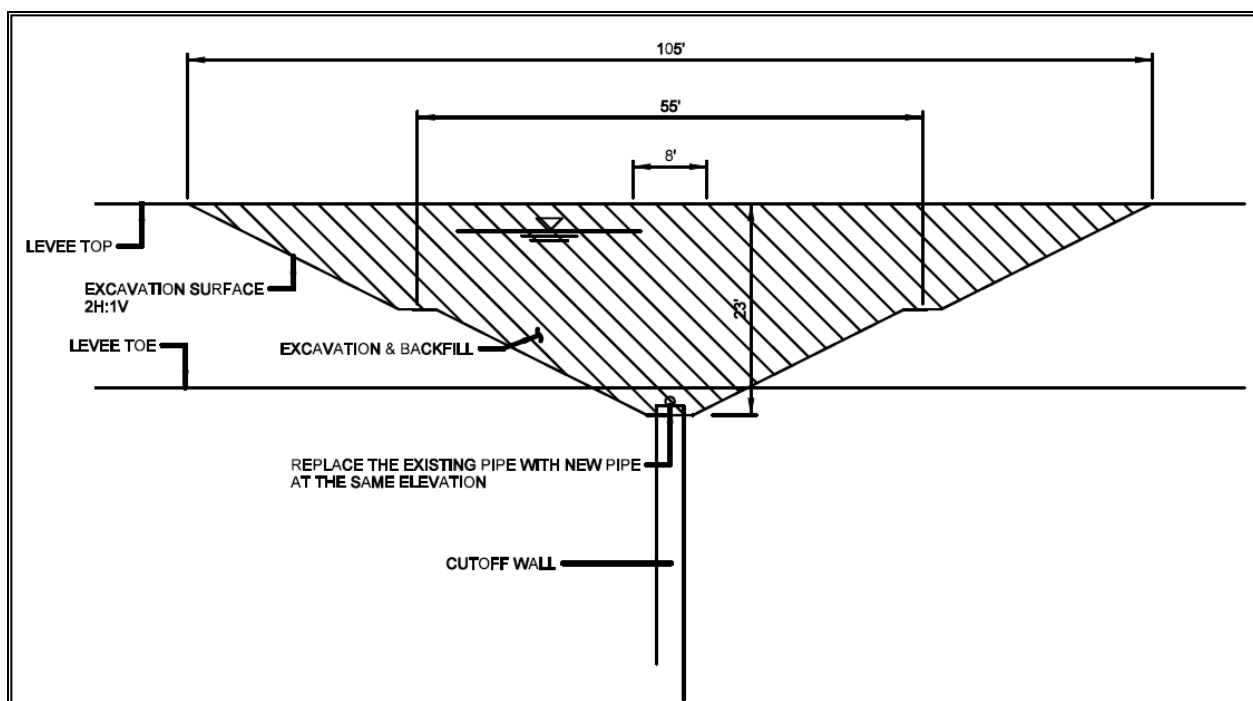


Figure 2-34B – Encroachment Type 3B – Profile

2.5.4 Type 4

This group includes utilities those are crossing the levee prism, dated and don't meet the current standard, include: (1) Communication conduits crossing the levee prism below the DWSE, and (2) Minor pressurized pipelines crossing the levee prism below the DWSE. These pipelines and conduits will be removed (before the cutoff wall construction begins) and replaced

and relocated above the DWSE (after the cutoff wall construction completes) with proper pipe materials and positive closure devices.

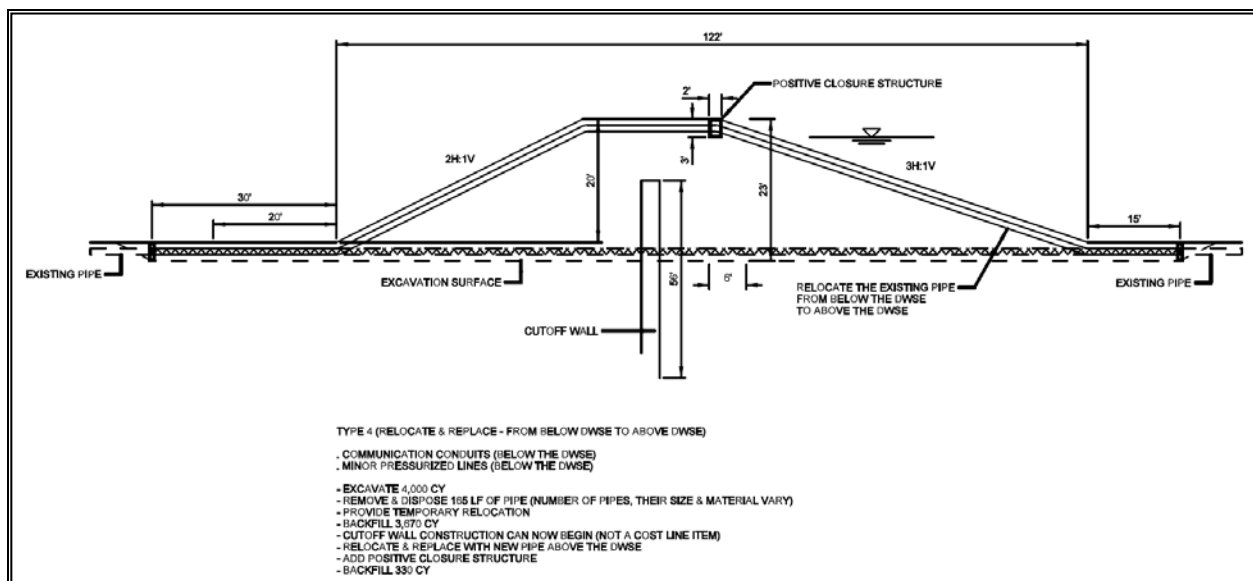


Figure 2-35A – Encroachment Type 4 – Section

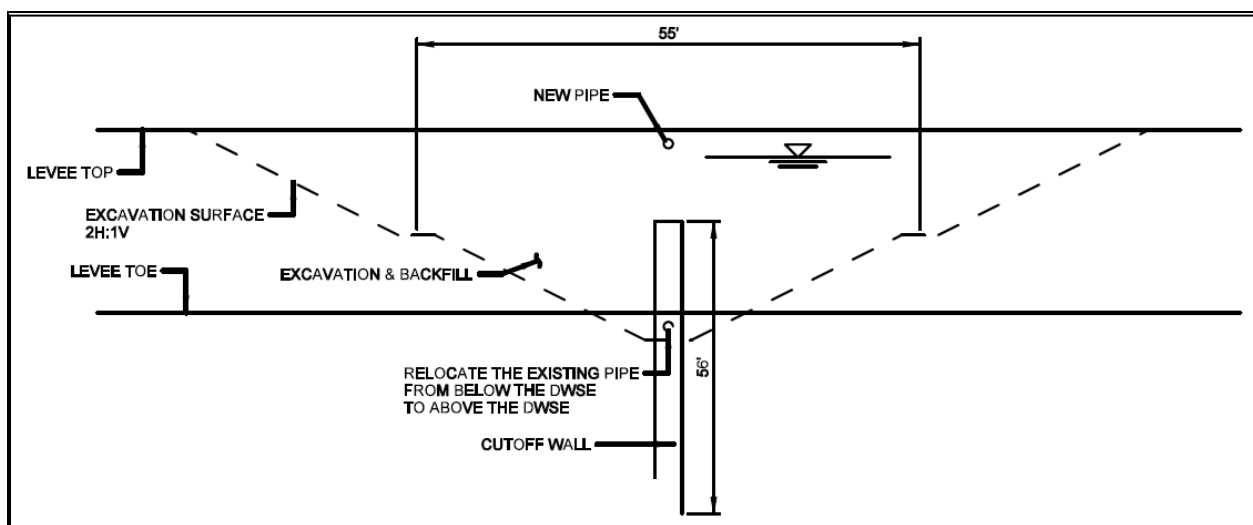


Figure 2-35B – Encroachment Type 4 – Profile

2.5.5 Type 5

This group includes bridges and railroads crossing the alignment of the existing levee. Deep Soil Mix (DSM) cutoff wall will be constructed at these locations.

2.5.6 Type 6

This group includes roads crossing the alignment of the new tall levee segments. Flood gate was initially considered as an option; however, because of the deep flood depth anticipated at these locations, these roads will be elevated up to the new top of levee.

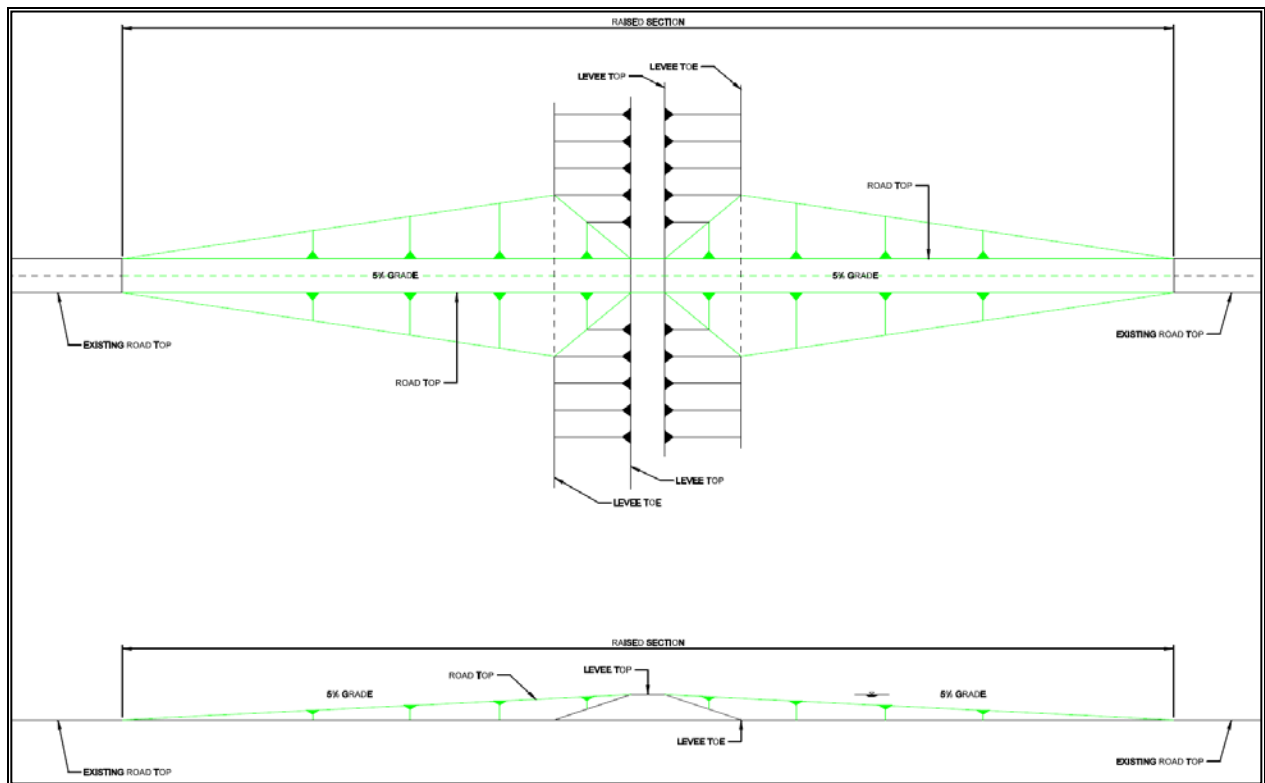


Figure 2-36 – Encroachment Type 6 – Plan and Section

2.5.7 Type 7

This group includes roads crossing the alignment of the new shallow levee segments. Because of the shallow flood depth anticipated at these locations, flood gate will be installed at these locations.

2.5.8 Type 8

This group includes canals crossing the alignment of the new levee segments. Relocation of these canals would result in high cost and impact. Therefore, the proposed remediation measure is to construct automatic closure structures at these canal crossings.

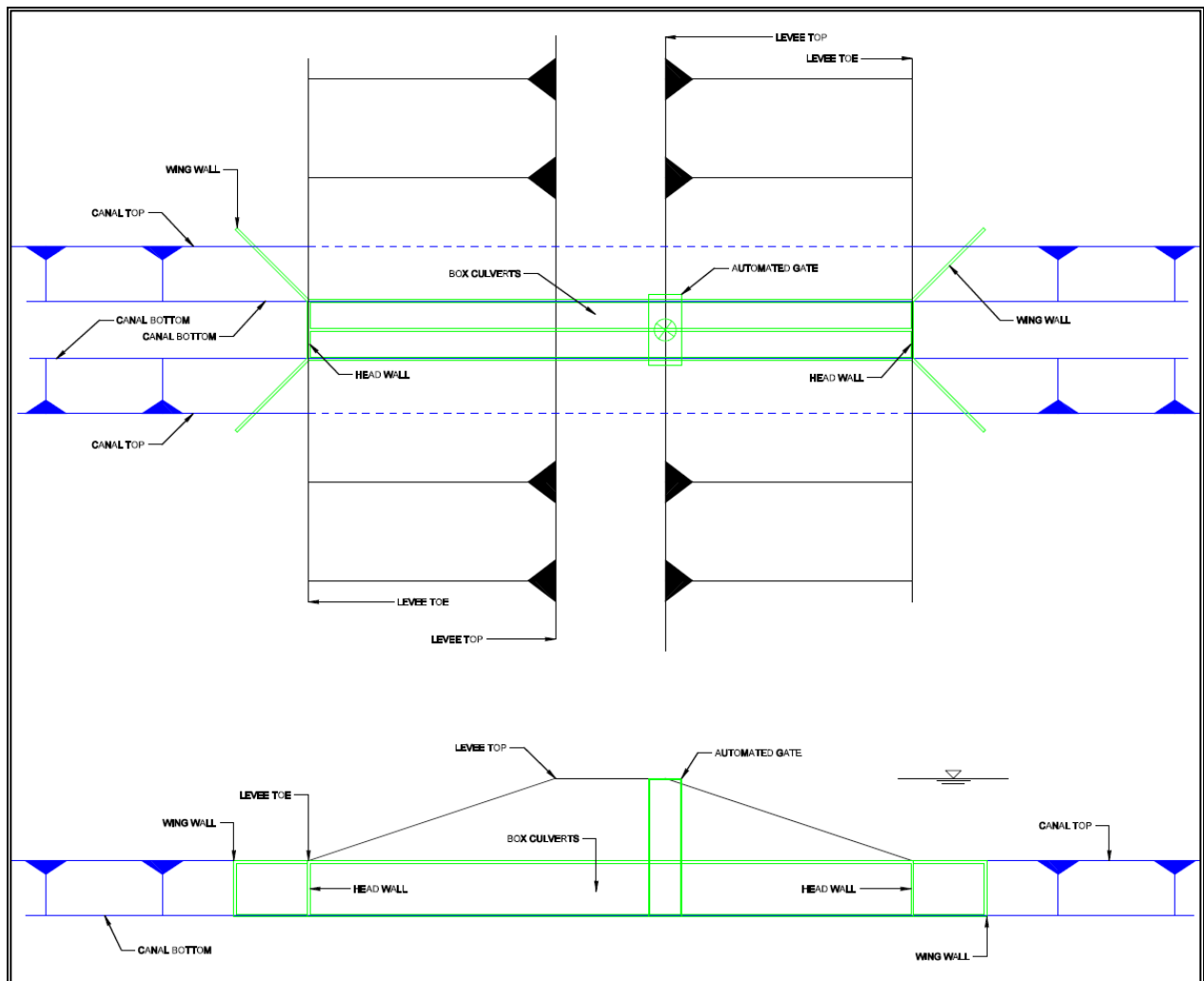


Figure 2-37 – Encroachment Type 8 – Plan and Section

2.5.9 Type 9

This group includes overhead power lines crossing the levee alignment. Temporary cutoff will be required to provide clearance for construction equipments where necessary. Power poles located within the proposed ROW will be relocated outside the proposed ROW, into a utility corridor.

2.5.10 Type 10

This group includes all physical structures (buildings, residential homes etc.) located within the proposed ROW of the existing and new levee segments. These structures will be relocated outside the proposed ROW.

2.5.11 Type 11

This group includes minor ditches and ponds located within the proposed ROW of the existing and new levee segments. These structures will be relocated outside the proposed ROW.

The Sutter Butte Main Canal (SBMC) falls within the proposed ROW at four locations along the FRWL alignment. Per Geotechnical Design recommendation, the SBMC encroachment was not specifically addressed during this phase of the study, however, captured as a part of the project's cost contingency during the Cost & Schedule Risk Analysis.

2.5.12 Type 12

This group includes all other overhead power poles, utility pipelines and conduits that are not crossing the levee alignment but located within the proposed ROW. These utilities will be relocated outside the proposed ROW, into a utility corridor.

2.6 Real Estate Requirement

The general Land, Easements, Rights-of-way, Relocation and Disposal Areas (LERRD)'s requirements include land acquisitions for levee footprint, O&M roads, utility corridors, temporary work areas, borrow and mitigation areas. The LERRD's requirements also include the relocation of physical structures (buildings, residential homes etc.) currently encroaching into the ROW.

The land acquisitions for levee footprint and O&M roads are necessary for construction, operation and maintenance of project features. The levee's and O&M road's footprints were established based on the final levee geometry (shown in figure 2-10A to 2-29B) and based on the distributions of typical levee improvement measures (shown in table 2-5A and 2-5B). In the figure, the levee footprint is the base width from the landside toe to the waterside toe of levee/berm. The landside O&M road is a 20-foot corridor along the landside toe of the levee/berm. The waterside O&M road is a 15-foot O&M corridor along the waterside toe of the levee/berm.

Additional land acquisitions for utility corridors, temporary work areas, borrow and mitigation areas were considered but not specifically addressed during this phase of the study. The utility corridor (approximately 20ft beyond the PRE for O&M roads) may be needed for relocation of utilities parallel to the project's alignment outside of the proposed ROW. Temporary work areas, borrow and mitigation areas are necessary for construction of the project features. These additional real estate requirements were not specifically identified and estimated as lump sum percentages of the total real estate requirements.

The number of physical structures to be relocated was estimated based on the ROW requirements (see paragraph 2.4.2).

2.7 Quantity Development

2.7.1 Levee and Cutoff Wall Constructions

The quantity estimates for levee and cutoff wall constructions (e.g. excavation and backfill, cutoff wall area etc.) were completed using the parametric approach. In this approach, the quantities were estimated as products of sectional area and length of different types of levee improvements. The sectional areas of levee improvements were based on the levee geometry shown in figure 2-10A to 2-29B. The lengths of the levee segment where a typical improvement measure applied were based on the distribution shown in table 2-5A and 2-5B. Refer to the URS Parametric Cost Estimating MII Toolbox for the quantity estimates for levee and cutoff wall constructions.

2.7.2 Improvements and Relocations of Encroachments

The quantity estimates for encroachments (type 1 through 12) are shown in enclosure 4, Encroachment Improvements & Estimates, based on the recommendations provided in paragraph 2.5.

CHAPTER 3 – ALTERNATIVE DESCRIPTIONS

3.1 General

Based on table 2-3 and 2-5B, the project features included in each potential alternative will be as follows:

Table 3-1 – Draft Array of Potential Alternatives

Reach	SB-1	SB-2	SB-3	SB-4	SB-5	SB-6	SB-7	SB-8
Stability Berm								
Stability Berm with Relief Wells								
Seepage Berm								
Gravel Stability Berm		14,075	3,130	10,705	57,229	73,581	16,865	60,019
Waterside Soil-Bentonite Slurry Cutoff Wall								
Centerline Soil-Bentonite Slurry Cutoff Wall		58,325	15,650	38,375	142,517	282,108	79,250	163,442
New Levee			42,750	34,250				
New Levee w/ Centerline SB Slurry Cutoff Wall			32,250	20,750				
Levee Crest Widening		95,300	31,300	61,600	95,300	142,200	123,200	123,200

Detailed description of the alternatives is discussed in paragraph 3.2

3.2 Alternative Descriptions

3.2.1 Alternative SB-1

Under this alternative, the Federal government would take no action toward implementing a specific flood risk remediation measures. See plate 1-1.

3.2.2 Alternative SB-2

This alternative includes fix-in-place Feather River levees from Sunset Weir to Star Bend (see plate 1-2), and includes fix-in-place levee structural measures and non-structural measures. The structural measures are shown in table 3-1.

3.2.3 Alternative SB-3

This is a primarily non-structural alternative that includes the construction of a new levee surrounding Yuba City (see plate 1-3) and utilizing fixed-in-place eastern sections of the existing levee, and includes fix-in-place levee, new ring levee structural measures and non-structural measures. The structural measures are shown in table 3-1. Two new pump stations were assumed to be required to address interior drainage.

3.2.4 Alternative SB-4

This alternative is a non-structural/structural hybrid that includes fixing-in-place the Feather River levees north of Yuba City from Shangahi Bend to Thermalito, and the construction of a new levee on the south and west of Yuba City (little J). See plate 1-4. Fix-in-place levee and new levee structural measures and non-structural measures are included in this alternative. The structural measures are shown in table 3-1. This alternative assumes two new pump stations to address interior drainage.

3.2.5 Alternative SB-5

This alternative is inclusive of alternative SB-2, and further extends levee fix-in-place improvements north to Thermalito Afterbay (see plate 1-5), and includes fix-in-place levee structural measures and non-structural measures. The structural measures are shown in table 3-1.

3.2.6 Alternative SB-6

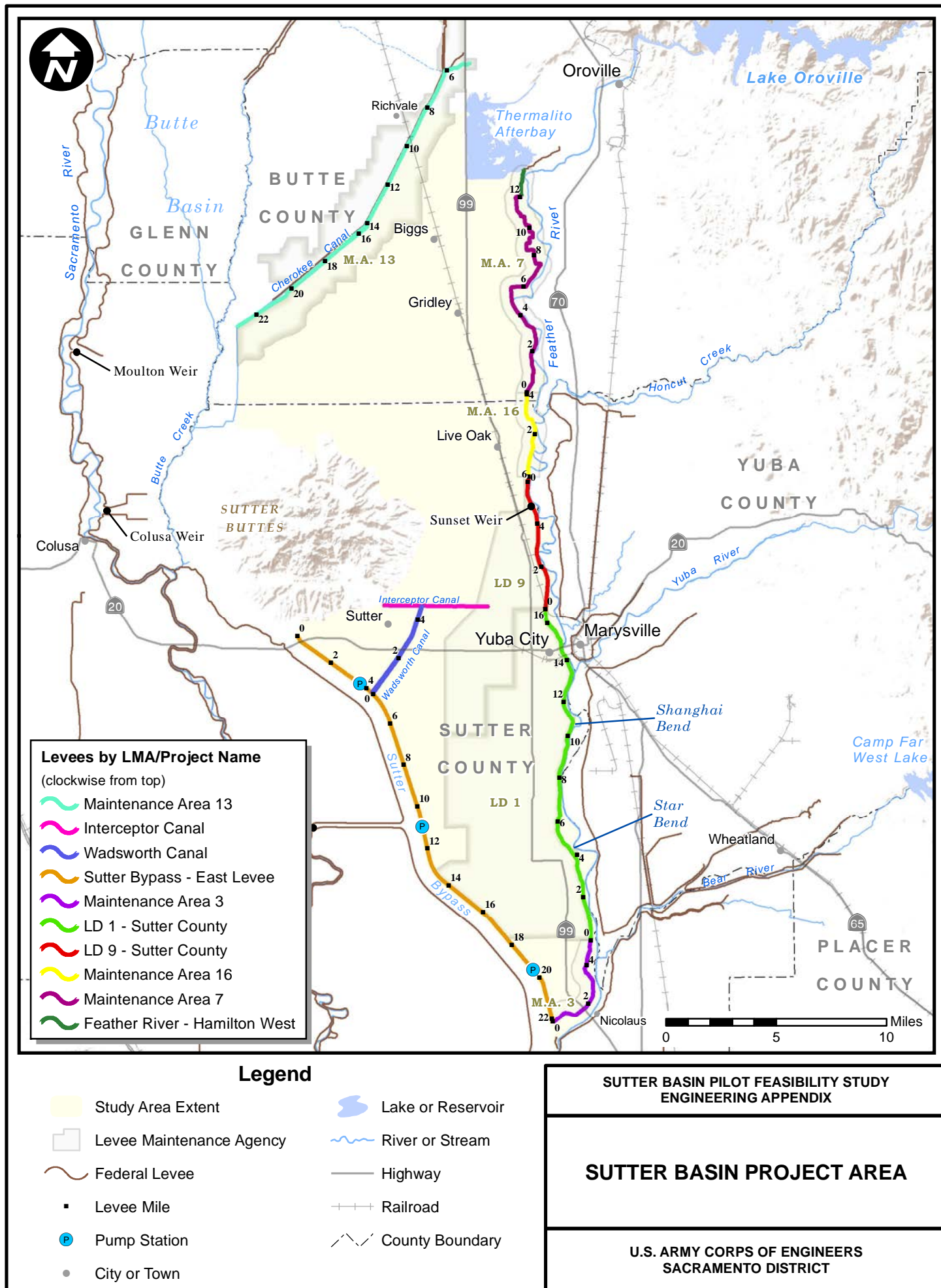
This alternative consists of the Sutter Bypass/Wadsworth Canal Levee fix-in-place improvements and fix-in-place levee improvements to all Feather River Levees (see plate 1-6), and includes fix-in-place levee structural measures and non-structural measures. The structural measures are shown in table 3-1.

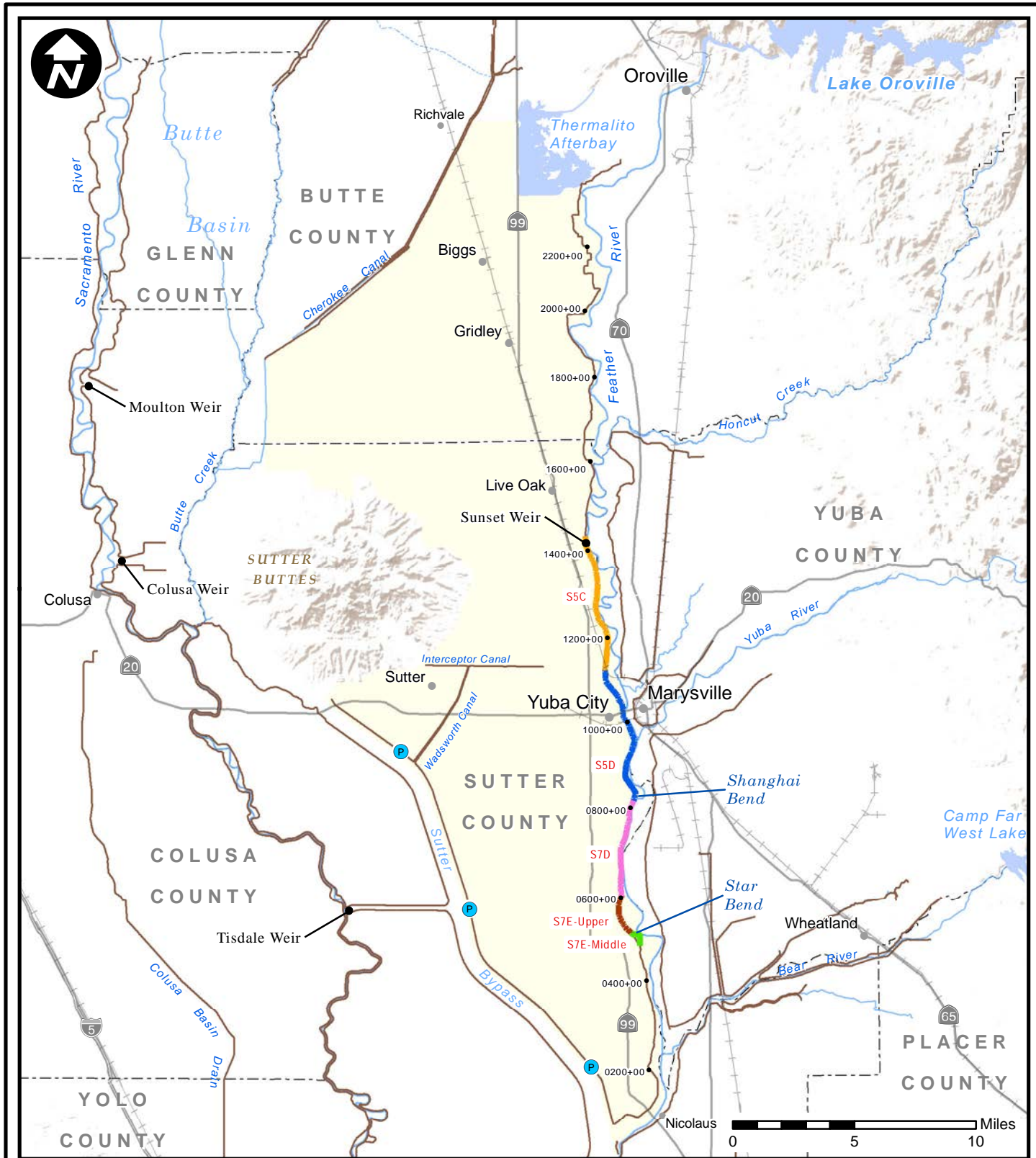
3.2.7 Alternative SB-7

This alternative includes Alternative SB-2 and extends Feather River fix-in-place levee improvements south of Yuba City to Laurel Ave (see plate 1-7), and includes fix-in-place levee structural measures and non-structural measures. The structural measures are shown in table 3-1.

3.2.8 Alternative SB-8

This alternative is inclusive of Alternative SB-7 and extends Feather River levee improvements north to Thermalito (see plate 1-8), and includes fix-in-place levee structural measures and non-structural measures. The structural measures are shown in table 3-1.





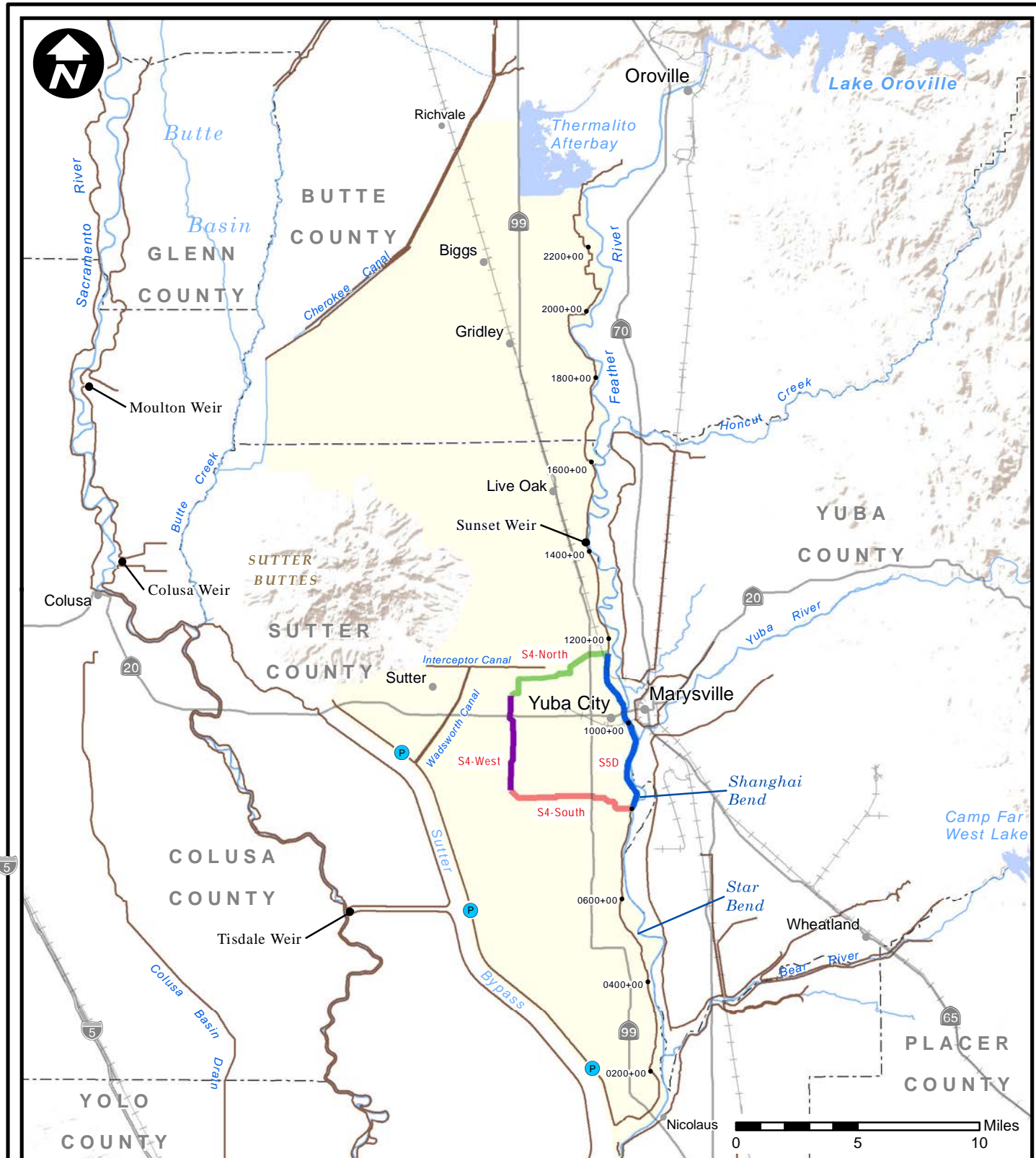
Legend

- | | |
|--|---|
| Study Area Extent | Lake or Reservoir |
| S5B Project Reach | ~~~~~ River or Stream |
| ~~~~~ Federal Levee | ——— Highway |
| • Stationing Point | + + + Railroad |
| P Pump Station | / / / County Boundary |
| • City or Town | |

**SUTTER BASIN PILOT FEASIBILITY STUDY
ENGINEERING APPENDIX**

ALTERNATIVE SB-2: MINMAL FIX-IN-PLACE FEATHER RIVER LEVEES: SUNSET WEIR TO STAR BEND

**U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT**



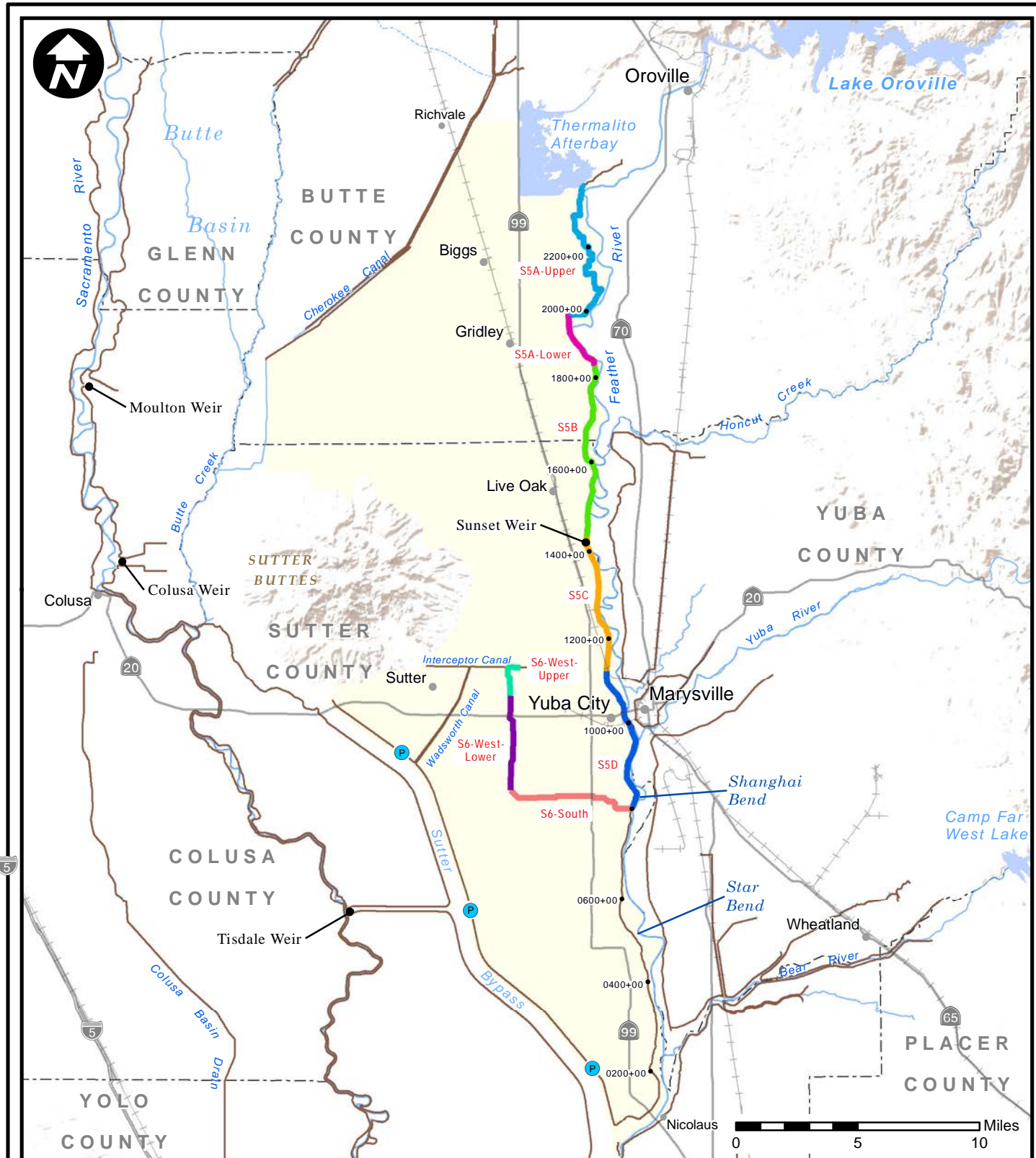
Legend

- | | |
|--|---|
| Study Area Extent | Lake or Reservoir |
| S5B Project Reach | ~~~~~ River or Stream |
| Federal Levee | Highway |
| • Stationing Point | Railroad |
| P Pump Station | County Boundary |
| • City or Town | |

SUTTER BASIN PILOT FEASIBILITY STUDY ENGINEERING APPENDIX

ALTERNATIVE SB-3: YUBA CITY RING LEVEE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



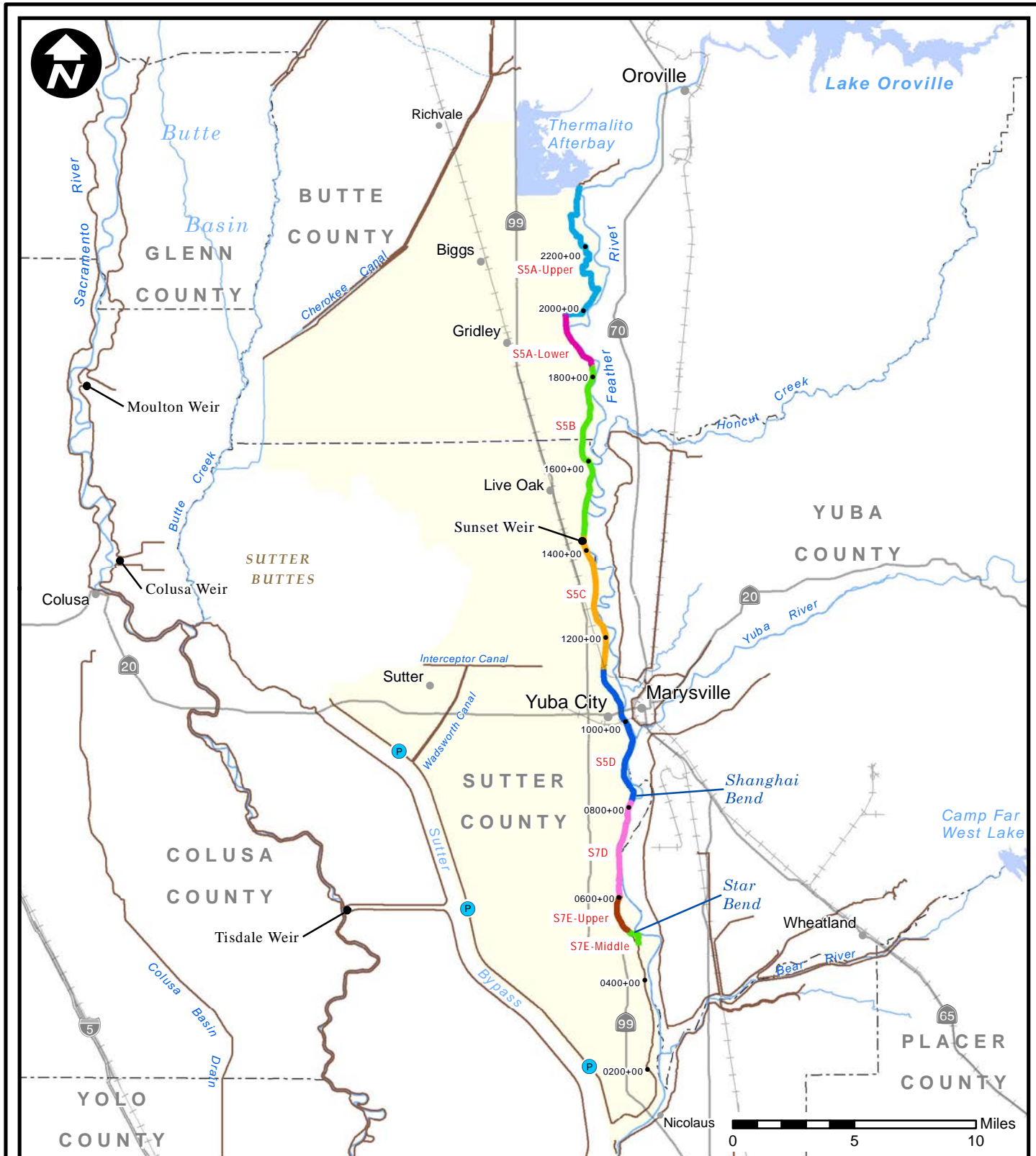
Legend

- | | |
|-------------------|-------------------|
| Study Area Extent | Lake or Reservoir |
| Project Reach | River or Stream |
| Federal Levee | Highway |
| Stationing Point | Railroad |
| Pump Station | County Boundary |
| City or Town | |

SUTTER BASIN PILOT FEASIBILITY STUDY ENGINEERING APPENDIX

ALTERNATIVE SB-4: LITTLE J LEVEE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



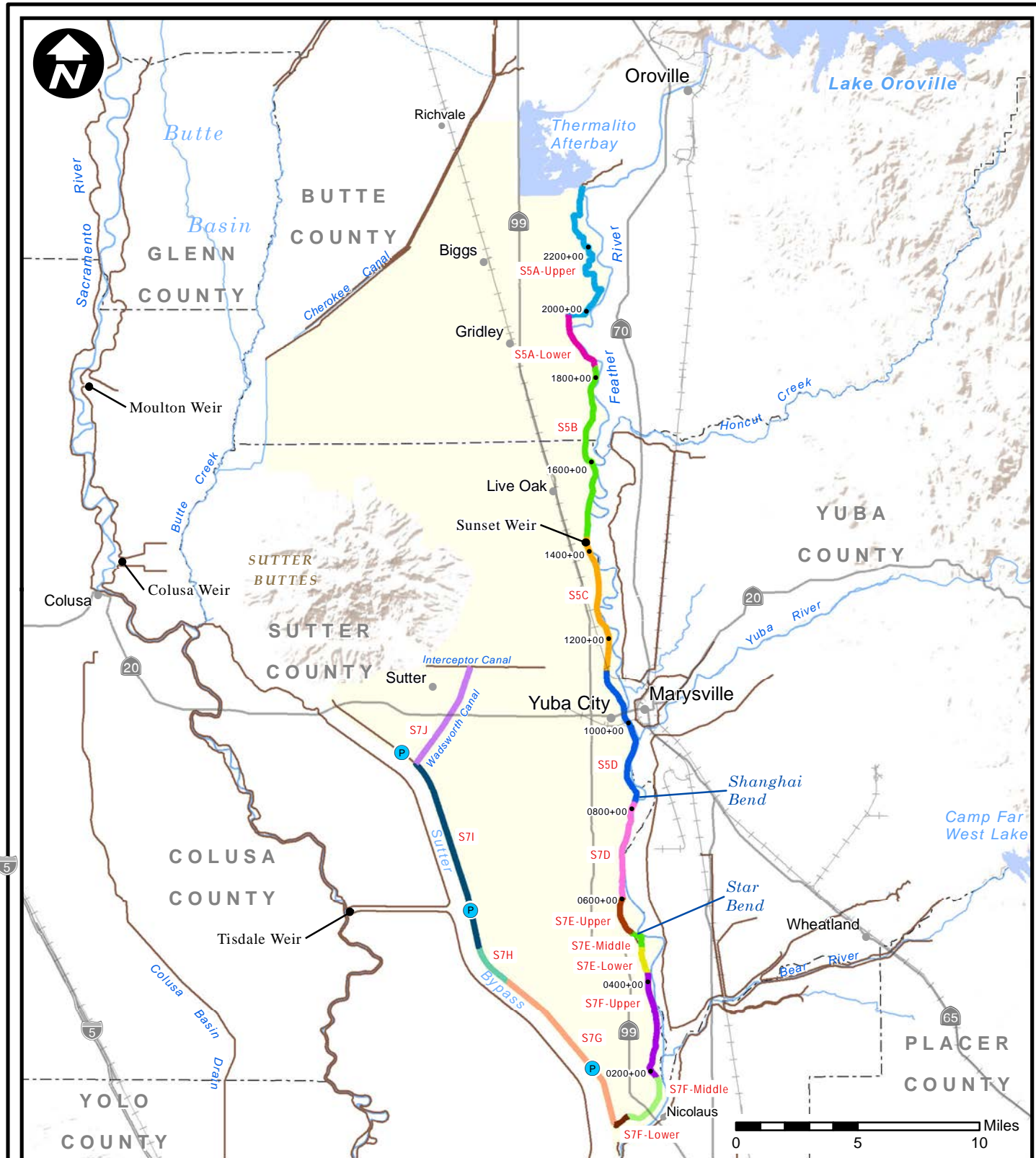
Legend

- | | |
|-------------------|-------------------|
| Study Area Extent | Lake or Reservoir |
| S5B Project Reach | River or Stream |
| Federal Levee | Highway |
| Stationing Point | Railroad |
| Pump Station | County Boundary |
| City or Town | |

SUTTER BASIN PILOT FEASIBILITY STUDY
ENGINEERING APPENDIX

ALTERNATIVE SB-5: FIX-IN-PLACE FEATHER RIVER LEVEES: THERMALITO TO STAR BEND

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



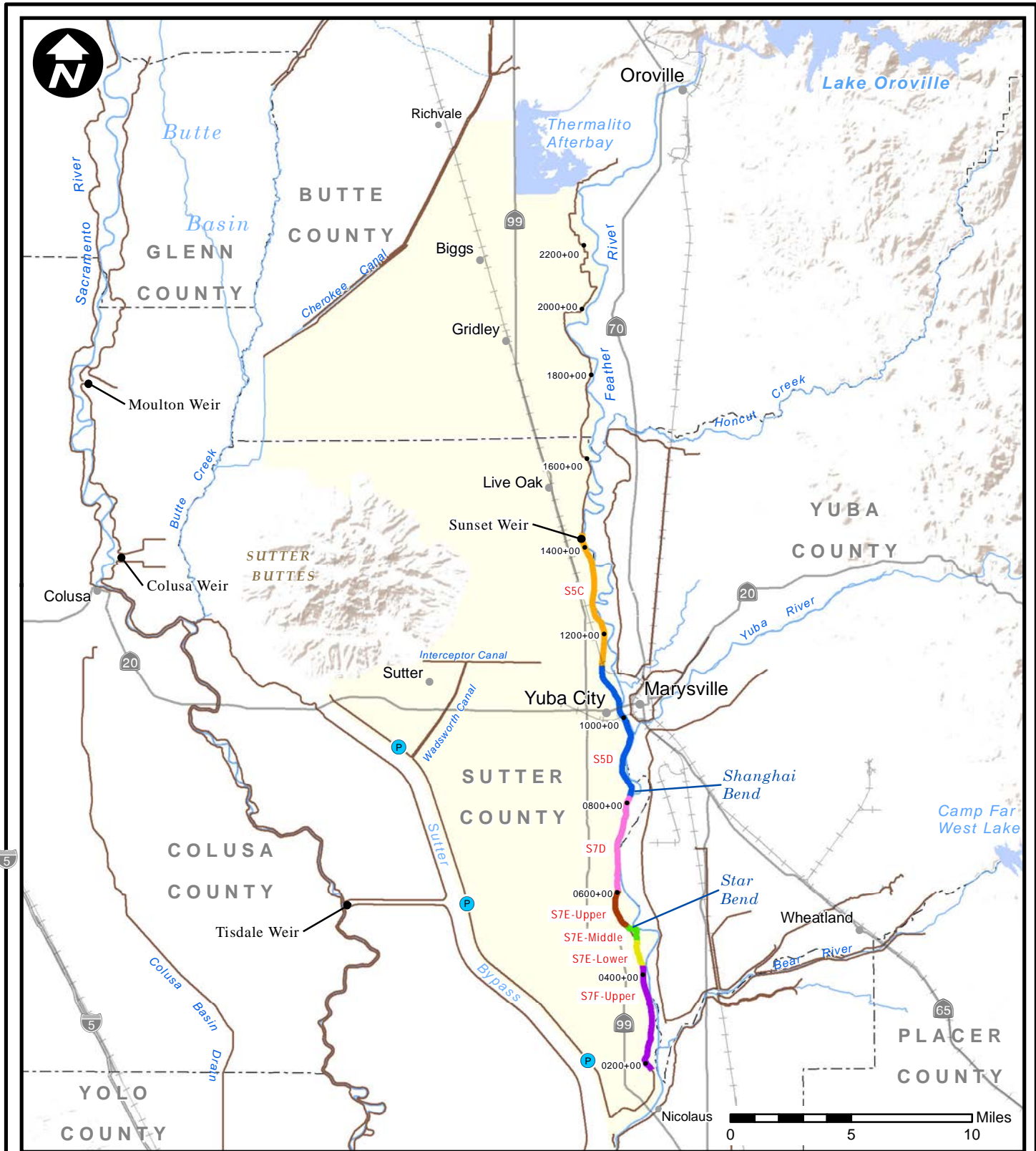
Legend

- | | |
|--|---|
| Study Area Extent | Lake or Reservoir |
| S5B Project Reach | ~~~~~ River or Stream |
| ~~~~~ Federal Levee | ——— Highway |
| • Stationing Point | + + + Railroad |
| P Pump Station | / / / County Boundary |
| • City or Town | |

SUTTER BASIN PILOT FEASIBILITY STUDY ENGINEERING APPENDIX

ALTERNATIVE SB-6: FIX-IN-PLACE FEATHER RIVER, SUTTER BYPASS, AND WADSWORTH CANAL LEVEES

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



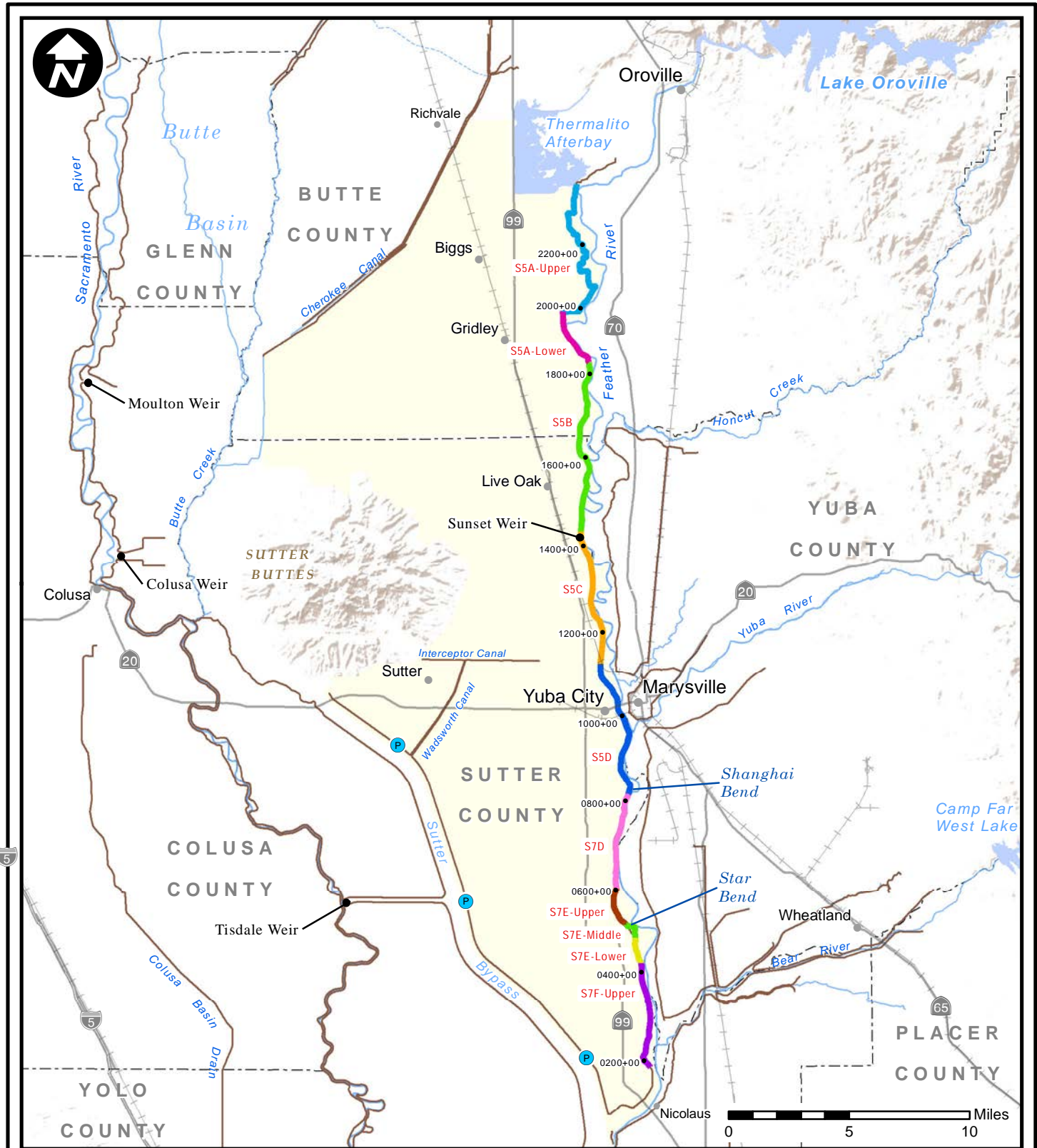
Legend

- | | |
|--|---|
| Study Area Extent | Lake or Reservoir |
| S5B Project Reach | ~~~~~ River or Stream |
| Federal Levee | Highway |
| • Stationing Point | Railroad |
| Pump Station | County Boundary |
| • City or Town | |

SUTTER BASIN PILOT FEASIBILITY STUDY ENGINEERING APPENDIX

ALTERNATIVE SB-7: FIX-IN-PLACE FEATHER RIVER LEVEES: SUNSET WEIR TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



Legend

- | | |
|-------------------|-------------------|
| Study Area Extent | Lake or Reservoir |
| Project Reach | River or Stream |
| Federal Levee | Highway |
| Stationing Point | Railroad |
| Pump Station | County Boundary |
| City or Town | |

SUTTER BASIN PILOT FEASIBILITY STUDY
ENGINEERING APPENDIX

ALTERNATIVE SB-8: FIX-IN-PLACE FEATHER RIVER LEVEES: THERMALITO TO LAUREL AVE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT